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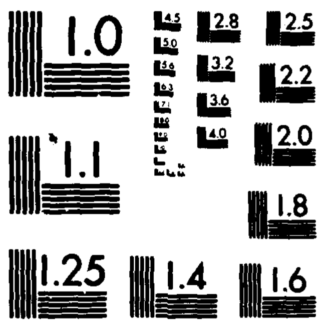

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Automated Low-Cost Weather Observation System (ALWOS)

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February 1982

Final Report

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16. Abstract

One of the primary objectives of this program was to design a developmental model ALWOS for the lowest possible cost. Reliability and maintenance costs over the life of the system were considered in addition to the initial purchase and installation costs. To this end, field proven, off the shelf components were used wherever possible throughout the system. Another primary objective was modularity of design. The hardware and software were constructed to allow flexibility in interfacing a variety of sensors or adding additional sensors to measure new parameters.

The ALWOS as configured at Dulles Airport is a low-cost and flexible system which can provide an automatic weather observation from the data acquisition, processing and display point of view, with the potential for good long-term system reliability. After a period of familiarization with the equipment and dealing with an assortment of system and sensor problems, the functioning of the system became relatively trouble-free.

Evaluation of the ALWOS supports the generally accepted concept that automated, low-cost weather observation systems can indeed perform such a function given suitable sensing devices.

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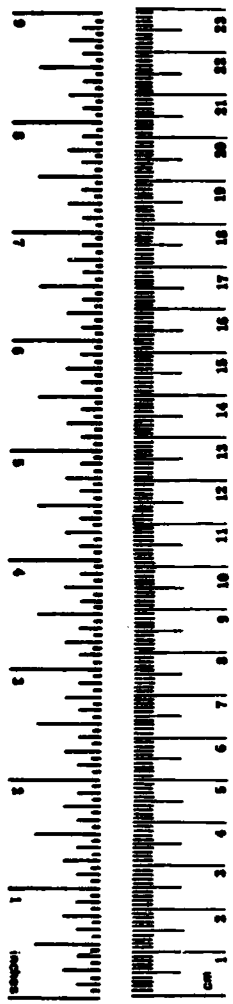
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

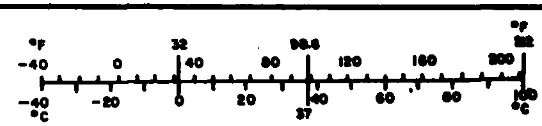
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conver[illegible] detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD [illegible] 1.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



ALWOS FINAL REPORT

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ALWOS EXECUTIVE SUMMARY

In February, 1978, a program to develop an Automated Low-Cost Weather Observation System (ALWOS) was initiated under Interagency Agreement DOT-FA73WAI between the National Weather Service (NWS) and the Federal Aviation Administration (FAA). The applicable engineering requirement (FAA-ER-451-153, dated February 13, 1978) specified the work required for the design, fabrication, test and evaluation of an ALWOS.

This program is part of an on-going automation effort by both the FAA and NWS and builds on the knowledge and experience gained from earlier automation programs such as AV-AWOS (Aviation - Automated Weather Observation System), AUTOB (Automatic Observing Station) and WAVE (Winds, Altimeter and Voice Equipment).

One of the primary objectives of this program was to design a developmental model ALWOS for the lowest possible cost. Reliability and maintenance costs over the life of the system were considered in addition to the initial purchase and installation costs. To this end, field proven, off the shelf components were used wherever possible throughout the system.

Another primary objective was modularity of design. The hardware and software were constructed to allow flexibility in interfacing a variety of sensors or adding additional sensors to measure new parameters.

The ALWOS system was installed at ~~the Dulles~~ International Airport, near Washington D.C., for evaluation. The weather parameters observed included: sky condition/cloud height, visibility, temperature, dew point, wind speed/direction, altimeter setting, precipitation occurrence, and thunderstorm (lightning) occurrence. Output from ALWOS was collected and compared with official weather observations taken by personnel from the collocated National Weather Service Office (WSO). Installation and maintenance of the system and sensors was provided by the NWS Integrated Systems Laboratory (ISL). Data collection and analysis were performed by members of the NWS Test and Evaluation Division (T&ED), whose offices are located adjacent to Dulles Airport. The field evaluation lasted for six months, 12 March through 15 September 1981. ALWOS was not used operationally during the field evaluation period.

Based upon the field evaluation of the ALWOS system, the following points should be emphasized:

a. The ALWOS as configured at Dulles Airport is a low-cost and flexible system which can provide an automatic weather observation from the data acquisition, processing and display point of view, with the potential for good long-term system reliability. After a period of familiarization with the equipment and dealing with an assortment of system and sensor problems, the functioning of the system became relatively trouble-free.

b. Evaluation of the ALWOS supports the generally accepted concept that automated, low-cost weather observation systems can indeed perform such a function given suitable sensing devices.

c. Performance of some of the various ALWOS sensors reinforces the important and still basically unfulfilled need for suitable instruments which can supply information that can be successfully incorporated into an automated observing scheme. This is particularly true for cloud, visibility, and thunderstorm detection data. The selected ALWOS ceilometer was unacceptable due to its consistently large output of missing data. The visibility sensor may have suffered from a period of serious unreliability (which eventually required replacement of the sensor). The selected ALWOS lightning detector as designed was unsuitable for human vs. machine comparisons and also displayed a high false alarm rate, at least during the early months of the evaluation.

d. Temperature, wind direction/speed, and altimeter setting observations generally compared favorably with the human observer. When the sensor was operating properly, dew point temperatures also compared favorably. Precipitation Yes/No was handled reasonably well by the selected ALWOS sensor. With proper sensor operation, reported ALWOS visibilities showed reasonable agreement with the human observer in many instances, but sensor location introduced a source of significant disagreement under certain visibility conditions.

e. It was not within the scope of the evaluation effort to thoroughly review the performance of the parameter algorithms. Algorithms were examined to the extent where discrepant ALWOS observations, inconsistencies in reporting, etc., were determined to be caused by the algorithms themselves or the manner in which the algorithms were programmed into the system.

1.0 INTRODUCTION

ALWOS is an acronym for Automated Low-cost Weather Observation System. The program is funded by the Federal Aviation Administration (FAA) and developed by the National Weather Service (NWS). The system, as tested, consists of a fully automated microcomputer system with sensors to measure cloud height and coverage, visibility, temperature, dew point, wind speed and direction, station pressure / altimeter setting, precipitation and thunderstorm occurrence with the capability to add other parameters as needed. Outputs from the system include: local and remote displays, local magnetic tape archive, local printout, remote telephone dial-up, as well as computerized voice output. FAA's need for an ALWOS-type system is for the more than 400 general aviation airports where little or no weather observations are currently taken. With an automated system installed at these airports, more of the general aviation needs could be served including air taxi or commuter traffic which require that weather observations be taken.

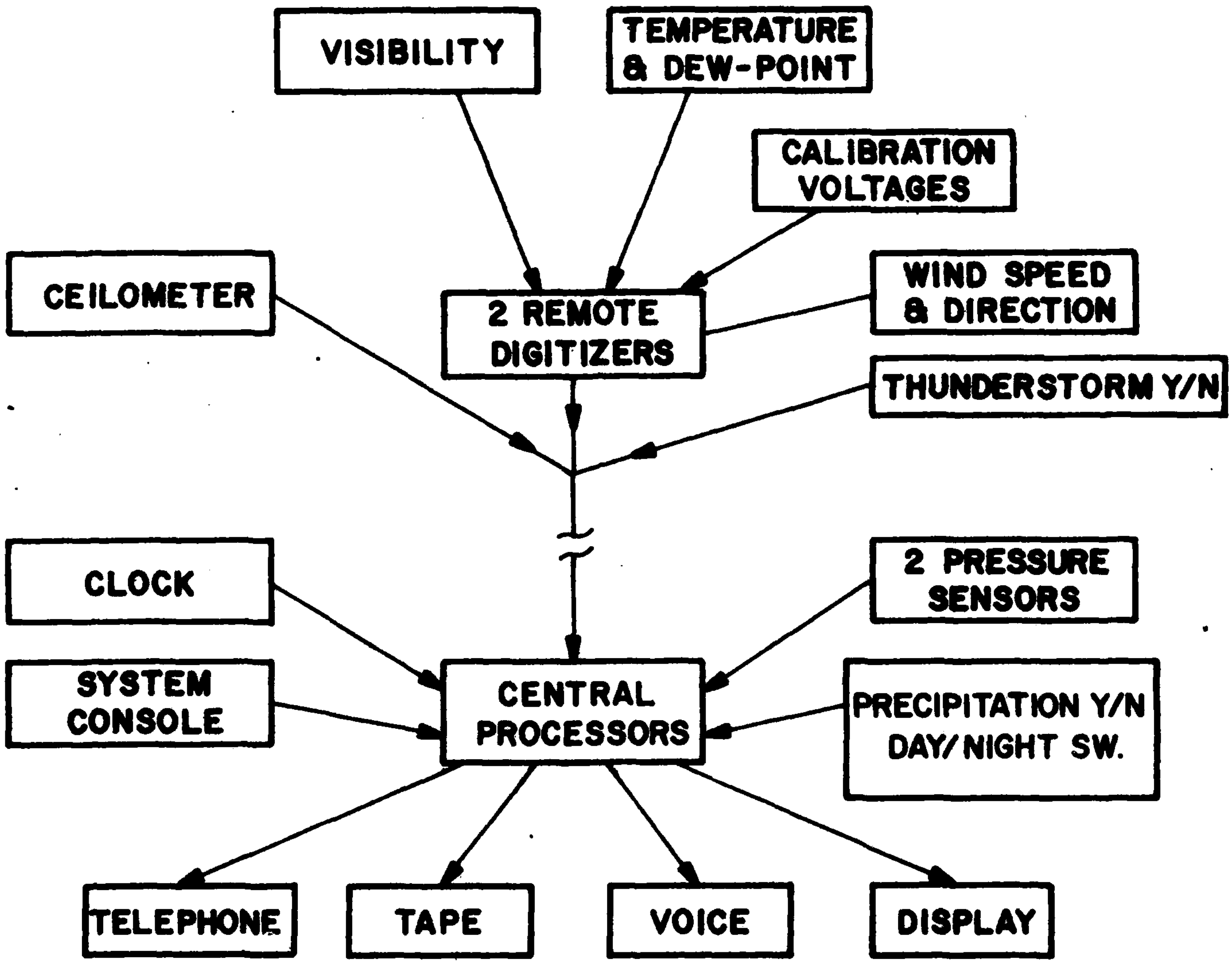
Tests performed on earlier NWS automated weather systems such as AV-AWOS (Aviation Automated Weather Observation System) and AUTOB (Automatic Observation - Clouds and Visibility) were used as a basis for the software algorithms and hardware configurations that were used in ALWOS. An important result from the AV-AWOS[1] test was that a single sensor could be used with a time averaging algorithm to measure cloud height/coverage and a single sensor for visibility at most airports. This result is important because today the cost of sensors to measure these two parameters far exceeds the combined costs of the processing equipment and the remaining complement of sensors. Otherwise, a relatively low cost automated weather observation system would not be feasible.

The purpose of the ALWOS test is to evaluate the overall system performance including processors, sensors, field electronics, system output peripherals an sensor processing algorithms. The results of the six month test at Dulles Airport are presented in this report as well as applicable hardware/software documentation. Software listings and other detailed hardware/software documentation are provided separate from this document.

[1] Aviation Automated Weather Observation System (AV-AWOS), Mar., 1979, Report No. FAA-RD-79-63.

2. Hardware Configuration

The ALWOS hardware configuration consists of four major functional components: sensors, remote analog to digital conversion system, data processing equipment, and system output peripherals (figure 2-1). Its basic functional design is similar to the AV-AWOS configuration in that cloud coverage and visibility data have been automated, remote analog sensor data is digitized before being sent to the main processor. and a processed weather observation has been assembled, formatted and sent to a variety of output peripherals as often as once per minute. The major differences between ALWOS and AV-AWOS are that the ALWOS system uses a single sensor to determine cloud height and coverage and a single sensor for visibility (AV-AWOS used 3 sensors for each), and that a relatively small microcomputer system rather than a large minicomputer system performs all the data processing functions. However, ALWOS offers the advantages of lower cost due to its use of single sensor clouds and visibility processing and higher reliability since its entire software program is stored in solid state memory rather than electromechanical disk storage used with the AV-AWOS system. The ALWOS system was configured in a modular design that allows easy modifications or expansion and to include as many quality control and self-check features as possible. Each of the four major functional components of the ALWOS system as well as a cost analysis is discussed in the following sections.



BLOCK DIAGRAM OF THE AUTOMATIC LOW-COST WEATHER OBSERVATION SYSTEM (ALWOS)

FIG. 2-1

2.1 Sensors

2.1.1 Ceilometer

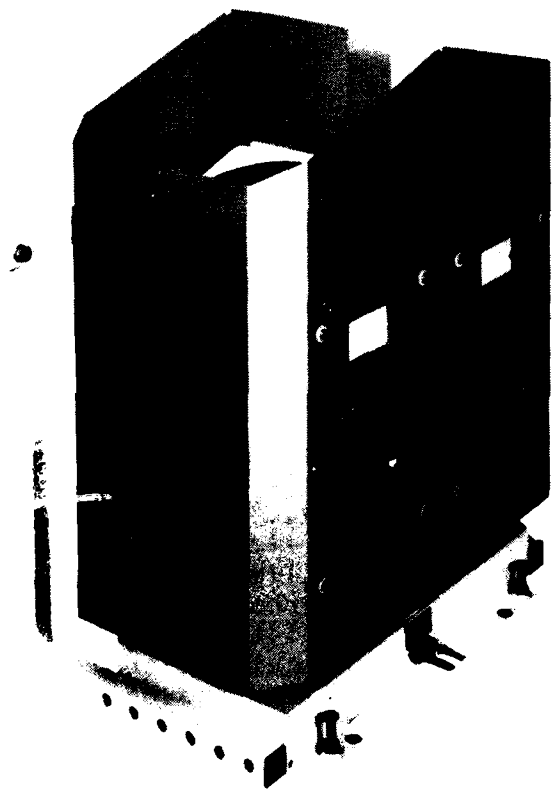
A prototype Gallium Arsenide (GaAs) laser ceilometer, built by IMPULSPHYSIK of West Germany, is used to measure cloud height/coverage for the six-month ALWOS test. This sensor was selected as the result of an RFP for the procurement of a laser ceilometer, released in February, 1978. The need for such a ceilometer is apparent when compared to the widely used, but aging, Rotating Beam Ceilometer (RBC). It offers the advantages of minimal sensor installation area since transmitter and receiver are co-located, in addition to increased reliability due to its solid state design as opposed to the rotating mechanical components used in the RBC.

The unit measures cloud height by transmitting low energy light pulses and measuring the time required for the light to be reflected off a cloud base and back into the receiver unit. Due to the extremely weak signal returns normally found in this mode of operation, several of the pulse returns are summed together to detect the presence of a cloud over a given height range or bin. Internal timing circuitry then slides the signal summing function in time to measure another height range or bin and continues this operation until the entire 3000 foot range is covered.

Its performance characteristics include providing cloud data at heights between 100 and 3100 feet with a range resolution of 50 feet, cycling through a complete range scan at least every 30 seconds, and designed to be "eye safe" when the human eye is exposed to the beam. The unit is also capable of measuring its own receiver sensitivity and transmitted laser power and sending this information along with the cloud data to a remote processor. Data is transmitted asynchronously in a serial bit format at 110 baud using an EIA RS-232 voltage interface. Each character transmitted contains 1 start, 2 stop, 1 odd parity, and 8 data bits. The 65 character data stream is transmitted for every range scan of the ceilometer, nominally every 28 seconds, and takes approximately 7 seconds to complete its message. An ASCII "STX" character begins the message followed by a receiver sensitivity character and a transmitted output power character. Characters 4 through 64 represent the backscattered energy measured in each of the 50 foot range bins from 100 to 3100 feet. The amount of energy detected is coded in binary where all zeroes represent the least amount of backscattered energy and all ones represent the most. Character 65 is an ASCII "EOT" representing the end of the message. Although new cloud range scan data is transmitted by the ceilometer every 28 seconds, the ALWOS cloud algorithm processes a running 25 minute (approx.) average and outputs a new cloud height/coverage message every 4 minutes (approx.). At initial system start-up, no message is available until the 25 minute buffer is filled. A photograph of the ceilometer is shown in figure 2-2. (For a more complete discussion of the ceilometer's technical details, refer to the IMPULSPHYSIK LASER CEILOGRAPH LD-WHL MANUAL)

2.1.2 Visibility

The EG&G model 207 forward scatter meter (figure 2-3) was selected by NWS to measure visibility for the ALWOS system test. A forward



IMPULSPHYSIK Laser Ceilometer

Figure 2-2

scatter visibility sensor was favored over the backscatter type because of the former's inherent ability to more closely follow the theoretical relationship to total scattering coefficient[2]. This comparison is based on typical scattering angles of 30 degrees for the forward scatter instrument versus 180 degrees for the backscatter sensor. In addition, the relative signal return levels are larger in the forward scatter instrument than in the backscatter type thus making the signal processing task somewhat easier. This particular instrument was selected based on the extensive testing performed by the Air Force and the reported low failure rates and simplicity of design. Field calibration of the unit is also possible through the use of a special apparatus that provides a standardized scattering medium.

The unit measures the atmospheric forward scattering coefficient in the 20 to 50 degree range. It consists of a light source and detector separated by approximately four feet (figure 2-4). Light from the source is projected in a cone-shaped beam over the angle of 20 to 50 degrees from the center axis toward the detector. The detector looks toward the light source and is optically configured to respond to light received in a similarly shaped volume. The intersection of these two optical alignments is a toroidal shaped volume approximately 2 feet in diameter and two feet thick. Optical scattering of the transmitted light into the receiver unit is a function of the aerosols contained in the sampling volume and, in the absence of absorption, determine the atmospheric extinction coefficient or visual range. Basically, the more light scattered into the detector, the lower the visibility and vice versa. Modulation of the light source and synchronous detection of the scattered light are done to eliminate interference from extraneous light sources.

Linear and positive logarithmic voltage outputs are available from the Model 207 and represent visibilities from 200 to 20,000 feet. An optional negative logarithmic output, installed in our test units, provides signal voltages for visibilities greater than 20,000 feet. However, the processing algorithm limits the upper range of reported visibilities to 8 miles. The internal electronics of the sensor are configured such that as the visibility increases from 200 to 20,000 feet, the voltage from the positive logarithmic output decreases from +5 volts down to 0 volts. For this range of visibilities, the negative logarithmic output remains at 0 volts. As the visibility increases above 20,000 feet, the positive logarithmic output remains at 0 volts while the negative logarithmic output goes from 0 volts to an upper limit of +5 volts. The linear output from the sensor is not used in our test configuration. To preserve the signal integrity, both the positive and negative logarithmic output voltages from the sensor are converted to their equivalent digital values by a nearby analog to digital (A/D) converter and then transmitted from the Dulles center field location back to the main processor at the Weather Service Office (WSO). Although the remote A/D converter samples the visibility sensor 10 times per second, the processing algorithm only inputs a new sample every 10 seconds and then computes a 10 minute running average for the processed output.

[2] Development and Calibration of the Forward Scatter Visibility Meter, Mar.,1974, Report No.AFCRL-TR-74-0145.

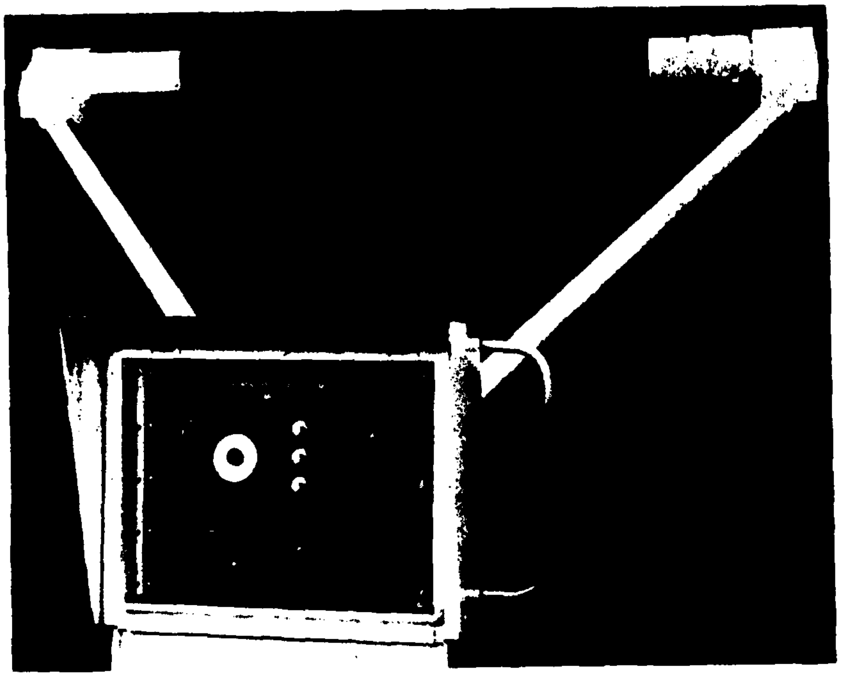


Figure 2-3, Visibility Sensor - EG&G Model 207 Forward Scatter Meter

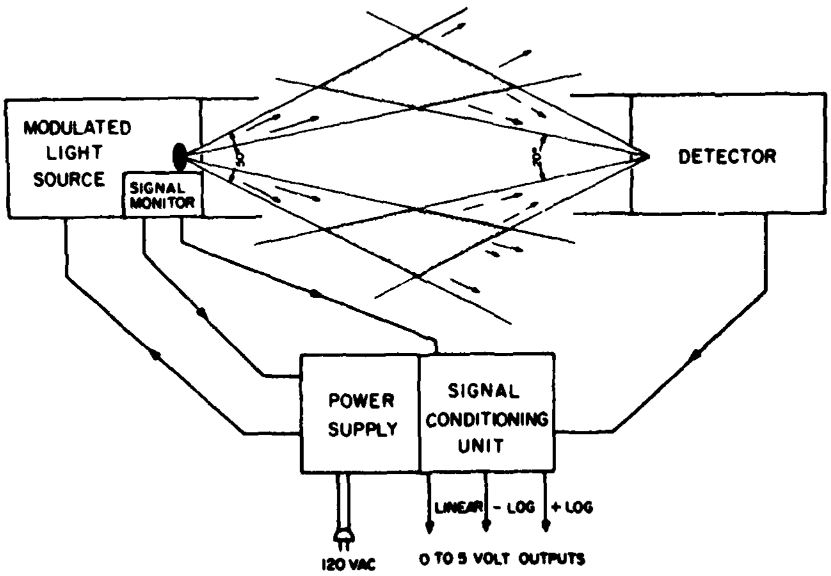


Figure 2-4, Schematic Diagram of the Forward Scatter Meter

2.1.3 Temperature and Dew Point

The basic transducers used for both temperature and dew point are made by the Yellow Springs Instrument Co. (YSI) and have been used in over 100 AMOS(Automatic Meteorological Observing System) and RAMOS(Remote Automatic Meteorological Observing System) systems built and operated by the National Weather Service for several years. They are enclosed in a Gill Aspirated Temperature-Dew Point Radiation Shield. A photograph of the enclosure is shown in figure 2-5. Both sensors are operated in a voltage mode configuration and their voltage outputs are converted to their equivalent digital values in the remote analog-to-digital converter, co-located with the sensors, before being sent to the processor in the WSO building.

Temperature data is obtained by placing the YSI thermistor, a triple element thermistor component whose resistance is a function of temperature, into a circuit where the voltage across the thermistor circuit varies linearly with temperature. In our application, the voltage output varies 10 millivolts per degree Fahrenheit.

The dew point probe consists of the same type thermistor component discussed above, a bobbin assembly and a protective shield. Construction of the bobbin assembly is made by using lithium chloride (LiCl) impregnated wicking wound around a spool and gold bifilar electrodes wound on top of the wicking. When the vapor pressure of the surrounding air becomes greater than that of the LiCl solution in the wicking then water is absorbed into the solution. The wicking becomes conductive and heat is generated when current is passed through the electrodes. Eventually a heat-moisture equilibrium is reached where the air vapor pressure equals that of the LiCl solution and that temperature is sensed by the thermistor component as the dew point temperature.

Specifications for both sensors are shown below.

RANGE...

Temperature:	-58 to +122 degrees Fahrenheit	
Dew Point:	-10 to +86 " "	

ACCURACY...

Temperature:	+/- 1.0 degrees Fahrenheit RMSE	
Dew Point:	+/- 1.5 " " "	(between +30 and +86 degrees F.)
	+/- 2.5 " " "	(between -10 and +30 degrees F.)

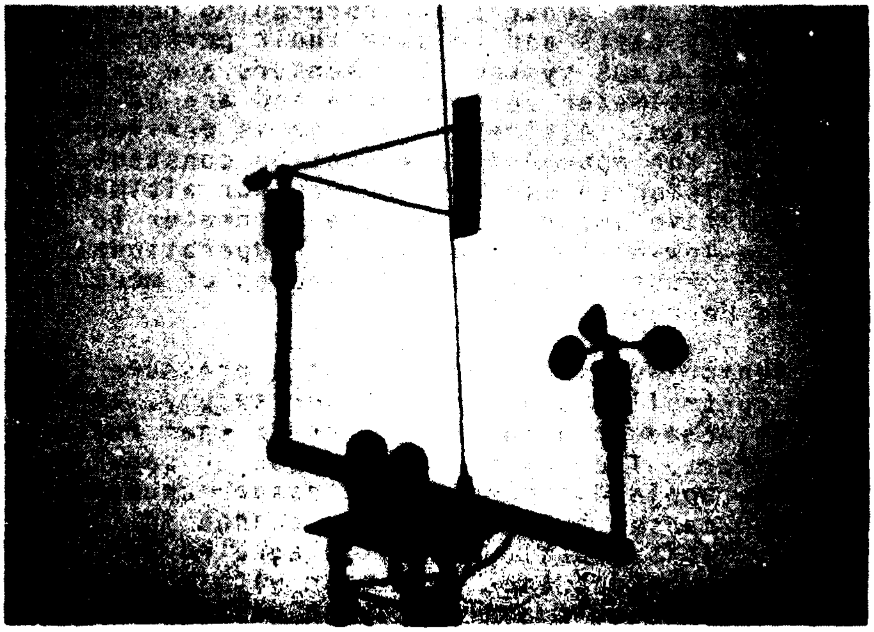
2.1.4 Wind Speed and Direction

The RAMOS (Remote Automatic Meteorological Observing System) wind speed and direction sensors have been selected for the ALWOS test because of their high accuracy, fast response, and low failure rate. The wind speed and direction sensors have been evaluated in several field installations and have proven their accuracy and reliability. A photograph of both units is shown in figure 2-6.

The wind speed sensor is basically a three cup anemometer driving a direct current generator, which is designed to provide a linear relationship between wind speed and generator output voltage. The

Gill Aspirated Temperature - Dew Point Enclosure

Figure 2-5



RAMOS Wind Direction and Wind Speed Sensors

Figure 2-6

output voltage of the generator is put across a potentiometer which is adjusted such that 1 knot equals 10 millivolts. With proper averaging, the output of the RAMOS wind speed data is designed to be within 2 knots or 5% from 0 to 125 knots of a 1-minute mean of the true value of the wind speed. The generator has an MTBF(mean-time-between-failures) of one hundred million revolutions, which in our application translates to about 2 years at an average wind speed of 8 knots. Wind tunnel tests have shown that the anemometer cup assembly can withstand wind speeds up to 175 knots.

Wind direction data is provided by a sensor that is basically a vane driving a multi-tap potentiometer, which is designed to provide a linear relationship between wind direction and the potentiometer's output tap voltages. The potentiometer is made of conductive plastic and is estimated to have a useful life of 10 years in the natural environment. The vane features a long moment arm and a polyurethane tail which provides a more sensitive and faster response than the current National Weather Service standard, the F420 steel vane. Wind direction output data is designed to be accurate to within 10 degrees from 0 to 360 degrees of a 1-minute mean of the true value of the wind direction.

2.1.5 Pressure/Altimeter Setting

In February,1977, NWS issued a technical specification for an accurate. rugged and low-cost pressure sensor that could be easily adapted to automated weather stations. The Airesearch Division of Garrett Corporation was selected from among several competing firms. All of their delivered units have been tested by NWS for temperature, linearity, hysteresis and power fluctuation effects on the sensor's data. In addition, the sensors are undergoing repeatability and long-term stability tests and to date their performance has been excellent. In the ALWOS system, two sensors are used to provide station pressure/altimeter setting data and are co-located with the microprocessor system. Altimeter setting is derived from the station pressure by using the appropriate elevation constants for Dulles Airport. The decision to use two sensors for altimeter setting was based on the relative importance of the parameter to aviation safety and the relative low-cost of the sensor. Operationally, both sensors have to track one another within 0.04 inches of mercury for altimeter setting data to be reported.

The pressure sensor assembly consists of a pressure transducer inside a temperature controlled oven and a power supply. A fused quartz diaphragm is attached to a moving electrode that forms one plate of a variable capacitor. The opposite electrode or capacitor plate is fixed and as the applied atmospheric pressure changes, the deflection of the diaphragm causes a corresponding change in the measured value of capacitance. This capacitance is integrated into a circuit which provides a voltage output that is linear with applied pressure. Conversion of the sensor's analog output voltage to the equivalent digital value is performed in a local analog-to-digital converter card located in the processing chassis. The range and accuracy of the sensor is listed below.

Range: 60 kilopascals (kPa) (17.718 in. Hg.) to 106 kPa (31.302 in. Hg.). The sensor's output voltage is linear from 0.000v to 4.600v at 0.001v/0.01kPa.

Accuracy: +/- 0.15 % of full range - 46 kPa (13.584 in.Hg.)
Worst case error = +/- 0.02 in.Hg.

2.1.6 Precipitation Yes/No

A precipitation yes/no sensor manufactured by Wong Laboratories and distributed through Science Associates, Inc., model #598(2), was selected for use in the ALWOS system. The sensor is designed to detect the presence of rain and snow through the use of two printed circuit-type grids. measuring approximately 2 x 3 inches, and mounted on a sloping surface sensor head that is thermostatically heated (figure 2-7). Precipitation is indicated whenever rain or snow bridge the conductors and cause a change in the detection circuitry's resistance. The heating element is used to assist in the evaporation of detected precipitation and to prevent false indications due to moisture condensation on the sensor grids.

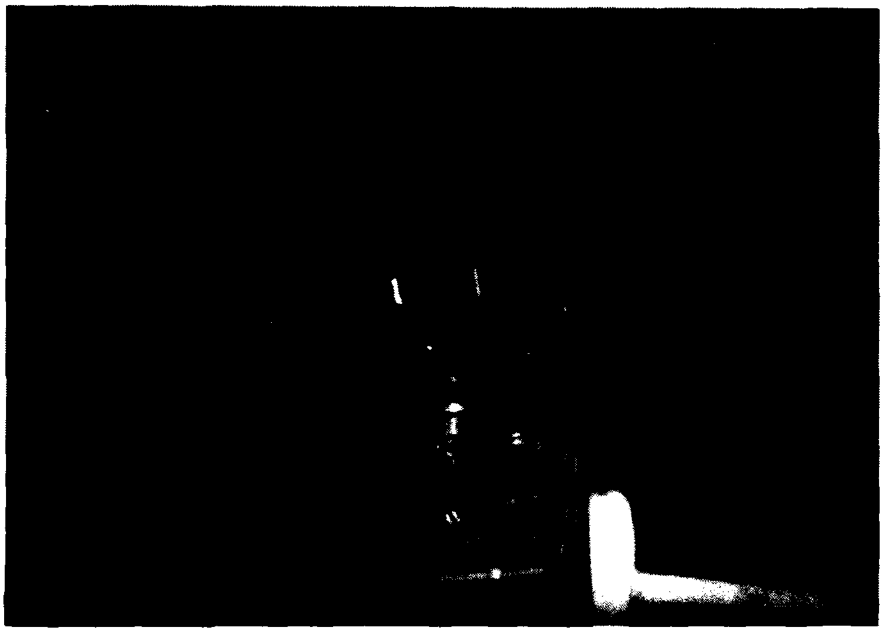
A 50-foot cable connects the sensor head to a control box which includes a gain control knob for varying sensitivity, an indicator light, a test button for checking performance through a reference resistance and input-output connection terminals. A relay contact closure is used to indicate precipitation occurrence to the ALWOS processor.

2.1.7 Thunderstorm

The thunderstorm sensor selected for ALWOS , model FCM-1, is a prototype unit manufactured by Atlantic Scientific Corporation. According to the manufacturer, the FCM-1 Lightning Warning System has an adjustable range up to 80 miles. A complete system is comprised of a central processor, a receiver module, antenna assembly and data interconnect cable. The sensor's central processor provides a display of the number of lightning discharges detected over a selectable period of time and an alarm which is energized whenever a lightning stroke is monitored. In the ALWOS application, however, the FCM-1 central processor is not used since the sensor's receiver module output is connected directly to the ALWOS processor. A 9 foot whip antenna and the receiver module are mounted at the top of a 20 foot Rohn tower located at Dulles' centerfield. The yes/no logic level output from the receiver module is buffered by a line driver before the data is sent to the ALWOS processor in the WSO building.

2.1.8 Day/Night

Day/night information is required by the visibility module in selecting the correct processing algorithm. The sensor chosen is manufactured by Precision Multiple Controls, Inc. and is simply a photoelectric cell that senses the amount of light and switches 115 VAC. off and on at its output as a function of day or night respectively. In the ALWOS application, the switched AC output of the sensor is used to drive a relay that provides open or closed contacts to the ALWOS sensing circuit. For the ALWOS test at Dulles, the day/night switch was mounted on the roof of the WSO building.



Precipitation Yes/No Sensor

Figure 2-7

2.2 Data Processing Equipment

Figure 2-8 shows a card-level block diagram of the ALWOS system including the nine printed-circuit cards that plug into the ALWOS system chassis and perform the data input, output and processing functions as well as the sensors and remote analog to digital conversion equipment located at Dulles' center field site. Each of the nine cards, with the exception of the sensor input card, access the systems' address, data and control bus. This bus architecture provides a convenient means for a CPU card to pass data and/or control to and from any other card connected to the bus as well as accessing memory locations on other cards to allow additional programming area. One of the ALWOS design goals was to eliminate any electromechanical storage devices such as magnetic disk units that are inherently less reliable than solid state memory. As a result, the entire ALWOS software program is contained in read-only-memory (ROM) integrated circuits mounted on the 2 CPU cards and the RAM/ROM & I/O Expansion card. A multi-master configuration is also possible where more than one CPU card can access the system resources over the same bus in a time-multiplexed arrangement. In the ALWOS system we have 2 CPU cards. The main or master CPU card controls the overall operation of the ALWOS system and the second CPU card is dedicated to ceilometer data processing. The function of each of the 9 cards and the remote analog to digital converter system are discussed in more detail in the following sections.

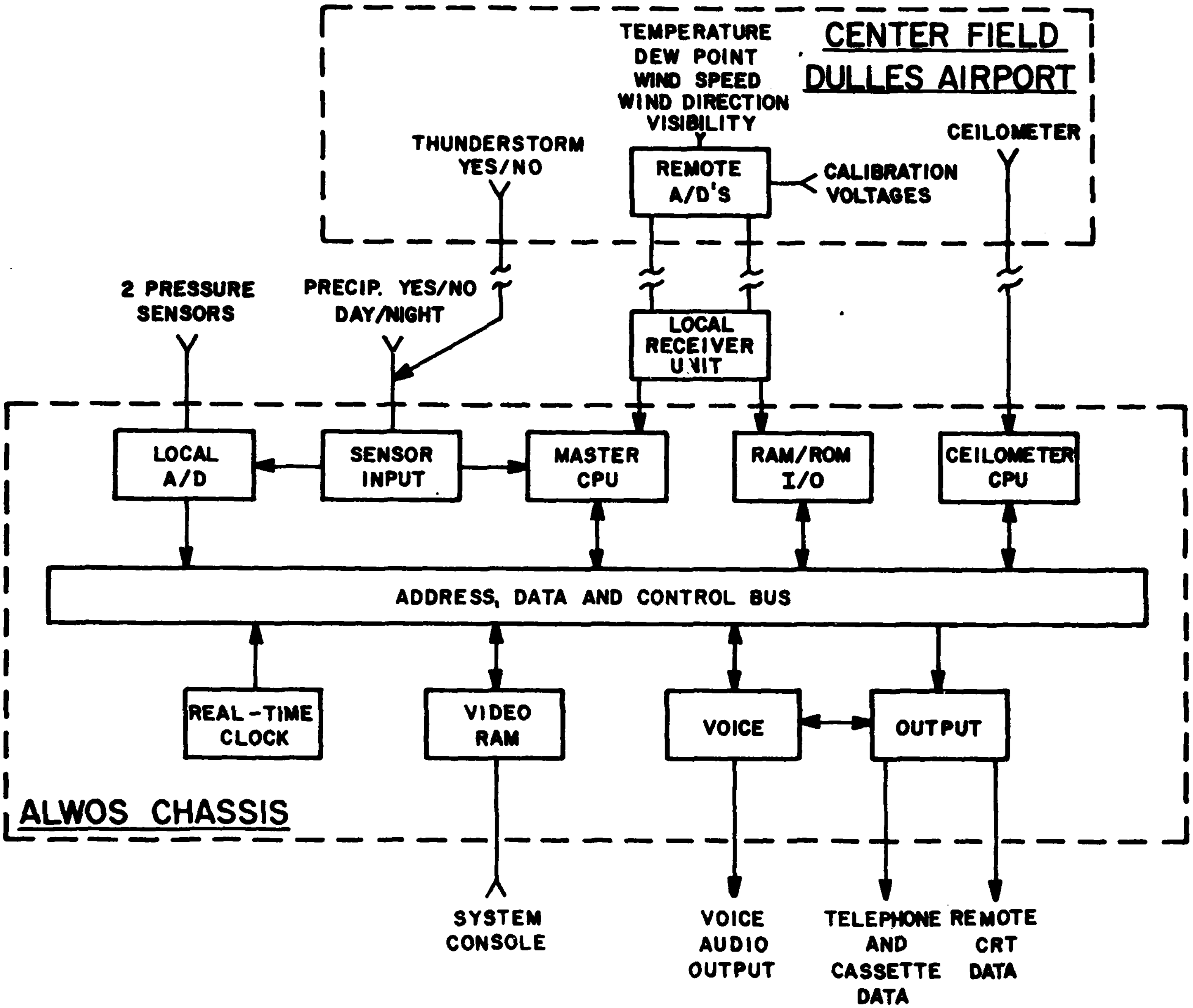
2.2.1 Computer Configuration

An MB80 Microcomputer Chassis built by Computer Marketing, Inc. was selected for the ALWOS system chassis. The MB80 provides a 9 slot card cage, backplane, power supplies, full ASCII keyboard, cathode-ray-tube (CRT) display and front panel control assembly. Its backplane is intended to interface with printed circuit cards that conform to the Intel "MULTIBUS" configuration. Included with the purchase of the MB80 system are an Intel iSBC 80/20-4 central processing unit (CPU) card and a Data Cube video random access memory (RAM) card to drive the CRT display. A dimensional outline of the MB80 chassis is shown in figure 2-9.

2.2.1.1 Main CPU Card

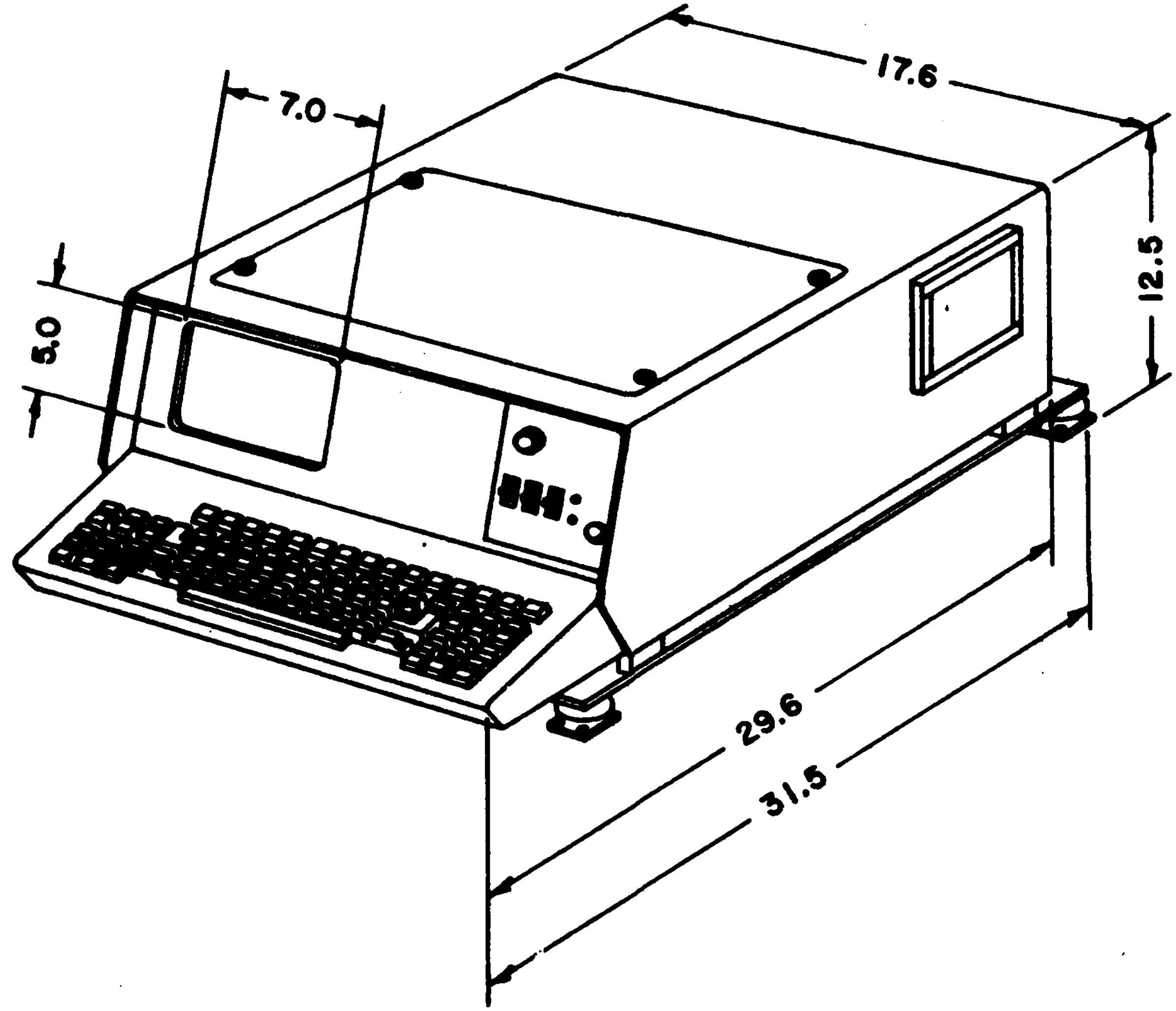
An iSBC 80/20-4 single board computer, manufactured by Intel Corp. and second-sourced by National Semiconductor Corp., is used for the ALWOS main central processing unit (CPU). Each iSBC 80/20-4 card is a complete computer system in itself and includes the CPU, system clock, 4k bytes of read/write random access memory (RAM), sockets for 8k bytes of non-volatile read only memory (ROM), priority interrupt logic and a variety of input-output interfaces.

In our configuration, the main CPU card is the master or executive of the ALWOS system operation. It's responsible for all data inputs, data processing and system outputs with the exception of ceilometer data. (A separate CPU card handles the ceilometer data processing and will be discussed in a following section.)



BLOCK DIAGRAM OF THE DULLES ALWOS SYSTEM - CARD LEVEL

FIG. 2-8



ALWOS MB80 CHASSIS

FIG. 2-9

The ALWOS hardware/software configuration is designed as a real-time interrupt driven system that incorporates a time scheduling executive. An Intel 8259 Programmable Interrupt Controller (PIC) provides hardware vectoring for eight interrupt levels. The fully nested interrupt mode was selected of the four modes available and operates such that interrupt level 0 remains fixed as the highest priority and level 7 as the lowest. Six separate external hardware interrupt lines are processed by the PIC on the main CPU card and they are:

level 2 - Keyboard
level 3 - Cloud Message Input Characters
level 4 - Remote A/D #1
level 5 - Remote A/D #2
level 6 - Real-Time-Clock
level 7 - Low-Level Voltage Detect

Keyboard data enters the system through a connector at the back of the Video Ram card (J3) . Each keystroke generates a level 2 interrupt request on the Video Ram card and is passed on to the main CPU card for servicing via the systems' MULTIBUS backpanel wiring. The processing of the keyboard interrupt and data is described in sections 3.2.2 Interrupt Handlers and 3.5 Keyboard Processor.

Remote A/D #1 data is presented to the main CPU card every 6 milliseconds, or 160 words per second, which is the conversion rate of the remote A/D system. Since there are 16 separate channels of data being converted. each channel or parameter is updated 10 times each second. The data is transferred 16 bits at a time through parallel I/O ports at connector J2 on the rear of the card. A "data ready" signal accompanies each new 16 bit word presented to the card and causes a level 4 interrupt to be sent to the CPU module signifying that new data is available for input. The format of the transferred data for both remote A/D #1 and #2 is described under sections 3.2.2 Interrupt Handlers and 3.4 Sensor Data Conversion and Processing.

The processed cloud message is transferred from the ceilometer CPU card to the main CPU card to be included as an integral part of the processed ALWOS output message. Processed cloud data of up to 50 characters (not to be confused with the ceilometer's raw data message) are sent in a serial RS-232 format at 110 baud to the main CPU via rear connector J3. Each character received generates a level 3 interrupt request on the main CPU card. A new cloud message is transmitted by the ceilometer CPU card approximately every 4 minutes.

Remote A/D #2 data is presented to the system at the same rate as remote A/D #1. However, remote A/D #2 data enters the system through connector J2 at the rear of the RAM/ROM and I/O Expansion card. For each 16 bit parallel word transferred, a level 5 interrupt request is generated on the RAM/ROM card and is passed on to the main CPU card via the "MULTIBUS" backplane for servicing. A more detailed discussion of the remote A/D system operation is contained in section 2.3 Remote Analog to Digital Converter System.

The real-time-clock card issues an interrupt request to the main CPU card once a second. Its level 6 request is also sent to the main CPU through the MULTIBUS backplane and is used as the basic time keeping mechanism for the time scheduling executive software. Servicing the clock interrupt is described in section 3.2.2 Interrupt Handlers.

A low voltage detection circuit, designed by NWS, is used to generate the level 7 interrupt request to the main CPU card and halt system operation. The purpose of the signal is to prevent erratic system behaviour whenever the voltage level supplied to the processing circuitry drops to a marginally low level for reliable computer operation. The low voltage condition could be caused by power supply failure, long or short term power line voltage drop or by the onset of a complete power failure. The main CPU card is programmed to respond to the level 7 interrupt by executing a "halt" instruction.

Event type sensor data and control signals are transferred in parallel format to and from connector J1 at the rear of the card. Day/Night, Precipitation Yes/No and Thunderstorm Yes/No data are presented in a binary format as a logical one or zero to the parallel interface and are sampled once each second. Two lines of the parallel I/O connector J1 are used to pass visibility information to the ceilometer CPU card. One bit is used to indicate whether visibility data is missing or not and the other bit is used to indicate whether the reported visibility is greater than 1.5 miles or not. The ceilometer CPU card uses this information in its decision to report cloud data missing or not and whether to report partial or total obscuration when the visibility is less than or equal to 1.5 miles.

A serial input/output port at the third rear connector, J3, is used to receive the ceilometer CPU's processed cloud message, transmitted approximately every 4 minutes. The format of the transmitted data is described in section 2.1.1, Ceilometer.

Random-Access-Memory (RAM), used for temporary data storage, is jumper selected on the main CPU card to occupy 4k bytes of total system memory space from 7000 through 7FFF HEX. Read-Only-Memory (ROM), used for permanent program storage, is jumper selected on the main CPU card to occupy 8k bytes of system memory from 0 through 1FFF HEX. A complete map of the ALWOS system memory configuration is found in section 3., Software Configuration.

Additional technical details on this card are provided in the Intel 80/20-4 Hardware Reference Manual.

2.2.1.2 Ceilometer CPU Card

An Intel iSBC 80/20-4 single board computer card is also used for the ceilometer input/output and data processing functions. The additional CPU card provides a means to input ceilometer data through a serial port every 28 seconds, store and process approximately 25 minutes of previous cloud data, and output the formatted message independent of the main CPU card's operations. Like the main CPU card, the ceilometer CPU card is a complete computer system in itself and contains the CPU, 4k bytes of RAM memory, 8k bytes of ROM memory, priority interrupt logic and a variety of input-output interfaces. Each CPU card operates independently of the other when on-board resources (memory, etc.) are addressed and can even share the remainder of the ALWOS system resources (additional memory and I/O ports, etc.) in a time-shared mode of the system's MULTIBUS structure.

Serial data is received from the Impulsphysik ceilometer at 110 baud, RS-232 format, consists of 65 characters and occurs every 28 seconds. A complete description of the ceilometer's input data format is found in Appendix A - Cloud Algorithm. The ceilometer CPU card's memory is configured in a non-standard arrangement that places its 80/20-4 RAM memory starting address at 1000 HEX instead of 3000 HEX. A memory map of the ceilometer CPU is shown below.

0000 to 09FF HEX	AUTOB Algorithm #2
0A00 to 0ED0 HEX	Cloud Base Height Algorithm
0EF8 to 0FFF HEX	Floating Point Subroutine
1000 to 17FF HEX	RAM
1800 to 1FFF HEX	Floating Point Subroutine

Approximately every 4 minutes, the processed cloud message is transmitted serially to the main CPU card via connector J3 at the rear of the card and is included with the other parameters to form the ALWOS system output message. However, two visibility conditions are required by the ceilometer algorithm before it can process the cloud data. These two conditions define whether a visibility value is available or not and if the reported visibility is greater than or less than 1.5 miles. This information, used by the cloud algorithm in determining obscuration conditions, is received by the ceilometer CPU card through two parallel I/O lines of connector J1. For additional information on the ceilometer CPU card's configuration or operation, see Appendix A, ALWOS Cloud Algorithms.

2.2.1.3 Clock Card

The clock/calendar timekeeping functions of ALWOS are provided by the MC1460 Microcomputer Timekeeping Module manufactured by Canada Systems Inc. This card is fully compatible with the "MULTIBUS" configuration and interfaces directly to the ALWOS system bus. Month, day, hours, minutes and seconds information are transferred through the "MULTIBUS" interface to the main CPU card for use by the time scheduling executive program. Automatic date correction is included for the number of days in each month. The MC1460 operates with an external battery, added to the MB80 chassis by NWS, to

ensure correct date and time data when system power is restored following a power failure. In addition, the card offers several software and switch selectable configurations, some of which are listed below.

Periodic interrupts to the main CPU card are available at any of 7 software selectable rates. A once per second interrupt rate was selected for ALWOS. Also, there are 8 possible levels, level 0 through level 7, that the 1 Hz interrupt can be presented to the main CPU's interrupt controller. Level 6 was switch selected for the real-time-clock interrupt.

Base address selection of 8 sequential I/O ports to pass clock data and control words to and from the main CPU card is also switch selectable. The starting I/O base address selected for ALWOS is C0 in hexadecimal (HEX) code.

A 50/60 Hz line frequency switch was initially set for 60 Hz operation and provided excellent long term accuracy when the ALWOS system was being developed. However, when the system was installed at Dulles Airport, excessive noise on the A/C power lines forced us to modify the clock board and install an external crystal oscillator as the basic timekeeping source.

For more detailed information on the clock card, refer to the MC1460 Installation and Operation Manual.

2.2.1.4 Internal Analog to Digital (A/D) Card

The Intel iSBC 711 Analog Input Board performs the basic functions of data acquisition of analog input signals under control of the ALWOS main CPU card. It consists of 8 differential/16 single ended channel multiplexer, input protection circuits, programmable gain amplifier, sample and hold amplifier, 12-bit A/D converter, memory mapped interface and control logic. The card is MULTIBUS compatible and its purpose in the ALWOS system is to digitize the analog voltage outputs of the two local pressure sensors to determine station pressure and altimeter setting.

In the ALWOS system, the card is programmed to operate in a random channel input mode, with a gain of 1 and jumper selected for a 0 to +5 volt input. The iSBC 711 utilizes a memory mapping technique which allows all control and data transfer operations to be referenced as memory instructions to a jumper selected base address plus offset. A base address of 5FF0 HEX was selected for ALWOS. Data acquisition begins when the master CPU issues a write command word that specifies the gain and channel selection to the iSBC 711 card. The main CPU then checks for the completion of the analog to digital conversion cycle by continuously reading a status register on the A/D card. When the end of conversion is indicated, the main CPU reads in the 12-bit data. A software timeout is included in this operation to prevent the system software from hanging due to possible malfunction of the card. Analog voltage inputs from

pressure sensors #1 and #2 interface the A/D card as channels 03 and 04, respectively. In addition, two corresponding offset voltages are input through A/D channels 15 and 14, respectively, and are added to the pressure data. These adjustable offset voltages originate from the Sensor Input Card and are used to calibrate the pressure sensor readings. For more detailed information on the card's operation, refer to the Intel iSBC 711 Hardware Reference Manual.

2.2.1.5 Voice Card

Speech Technology Corporation (STC) manufactures the model M180 Voice Generator card and is used in the ALWOS system to convert the processed weather observation into its equivalent spoken message. A computer analysis of the spoken ALWOS vocabulary was performed by STC to minimize the amount of storage required for the digitized vocabulary while striving to preserve the natural voice quality and intonation. The resultant digitized ALWOS vocabulary is stored in four programmable read-only-memory (PROM) modules that are inserted into the M180 card. Approximately 70 words, phrases and timed pauses or 70 seconds of speech are contained in the ALWOS vocabulary and are listed in figure 2-10. Each word or phrase is output by the card in audio form whenever the appropriate two-byte PROM address is sent to the Voice card. Input data rates to the Voice card may vary from two to four bytes a second to as low as two bytes in 4 seconds, depending on whether isolated words or connected phrases are selected from the vocabulary. Internal bit rates vary from 600 to 1100 bits per second when the digitized speech is converted to its analog output. Although the M180 Voice Generator card is compatible with the Intel MULTIBUS, word or phrase address data is transferred to the Voice card from the Output card via J1 at the rear of the card. For additional technical information on this card, refer to STC's M188 Voice Generator User's Reference Manual.

2.2.1.6 Output Card

The Output card, designed and built by NWS, provides data buffering and interfaces for the ALWOS system outputs. Remote display (CRT) data, remote telephone data access, local printer, local cassette and voice data are all handled by the Output card. The card receives its data from the main CPU card over the system's MULTIBUS interface. Three on board buffers, each addressed as individual I/O ports, allow the main CPU to store processed data into the Output card at set times and for the data to be transmitted to the output peripherals at their convenience. This configuration lessens the potential peak workload or duty cycle that the main CPU may encounter at system update times by allowing the Output card to handle most of the system I/O.

ALWOS Automated Voice Vocabulary

Altimeter
And
At

Broken

Calm
Ceiling
Clouds

Dew point

Eight
Eighth
Eighths
Estimated

Favored
Feet
Few
Five
Four
Fourth
Freezing rain

Greenwich

Half
Hundred

Less than

Measured
Minus
Missing
More than

Niner
Not available

Obscured
One
Overcast

PS100 (100 ms.pause)
PS200 (200 ms. ")
PS400 (400 ms. ")
PS800 (800 ms. ")
Partially
Peak gusts
Precipitation

Quarter
Quarters

Runway

Scattered
Seven
Six
Sixteenths
Sky

Temperature
Thin
Thousand
Three
Thunderstorms
To/Two

Visibility

Wind

Zero

Phrases

1. Dulles International Airport automated weather observed at:
2. This is a test
3. Sky condition missing
4. Indefinite ceiling
5. Index of visibility
6. Higher clouds detected
7. Clear below
8. Variable between
9. Favored runway changed from

Figure 2-10

The first output buffer, addressed as I/O ports B4 and B5 HEX, stores the system's one-minute observation at 00, 20 and 40 minutes after the hour and interfaces its data to the local cassette tape recorder, local system output printer and remote telephone data access. All three peripherals are connected in parallel to the buffer's RS-232 serial output. Data transmission begins when the system is polled via the telephone data access, nominally at 10, 30 and 50 minutes after the hour. If the poll is not received during the 20 minute interval then the computer forces the buffer to transmit its data at 19, 39 and 59 minutes after the hour.

The second buffer, addressed as I/O ports B2 and B3 HEX, is used to store and transmit data through a serial RS-232 interface to the remote CRT display located in the Dulles Airport control tower. This buffer updates and transmits the latest ALWOS observation every minute to the remote CRT.

The third buffer addressed as I/O ports B0 and B1 HEX, stores a series of addresses corresponding to words or phrases that are contained in the ALWOS system's voice message. These addresses are transferred in an 8-bit parallel format to the Voice card through conector J1 at the rear of the card. A new voice message is stored in the Output card every minute. Transfer of the vocabulary addresses from the Output card to the Voice card is initiated by the main CPU card. A schematic of the ALWOS Output (Data Storage Interface) card is provided under separate cover.

2.2.1.7 Sensor Input Card

The sensor input card was designed by NWS as a means of providing special purpose circuitry that allows increased interface flexibility to a variety of sensors. Included in the special circuitry are two adjustable pressure offset voltages that are used in the calibration of the two pressure sensors. The pressure offset voltages, #1 and #2, are interfaced through connectors at the rear of the card to channels 15 and 14 of the internal A/D card, respectively. In addition, a 3.333vdc calibration check voltage is generated on the card and tied to channel 13 of the internal A/D card. Software then compares the digitized value to be within predetermined limits as a quality control check of the internal A/D converter card. Voltage scalers, input filters and digital latches are also provided to interface the thunderstorm, precipitation and day/night sensors. This card receives power from the MB80 MULTIBUS interface but does not transfer any data or control signals over the bus. All input and output data transfers are done through the connectors at the rear of the card. A schematic of the Sensor Input Card is provided as a separate item.

2.2.1.8 Video Ram Card

A DATACUBE model VR-107 video RAM (random-access-memory) card is used to drive the local display characters on the ALWOS chassis' integral display. The card contains 2k bytes of RAM memory and is fully compatible with the Intel MULTIBUS configuration used in the ALWOS system chassis. Dual port memory provides a simple means of

writing ASCII characters on tne screen. Characters are written into or out of the RAM memory from the MULTIBUS side wnile the other port is used to refresh the raster-scan of the CRT display. A character need only be written to the appropriate location in the video RAM in order to appear instantly on the screen. The character generator provides 128 characters including upper and lower case. The display is normally formatted as 24 lines of 80 characters each for a total of 1920 characters but can be programmed to display larger characters in a 12 line by 40 characters per line format. Connectors J2 and J3 are provided at the rear of the card to interface directly to the CRT display and an 8-bit keyboard, respectively. Characters typed on the MB80's integral keyboard enter the video RAM card through a ribbon cable and cause an interrupt to be sent to the main CPU card. When a keyboard interrupt occurs, the main CPU reads the memory location that corresponds to the keyboard input port and processes tne keyboard command. In the ALWOS configuration, the 2k bytes of video RAM memory is jumper selected to occupy locations 6800 HEX to 6FFF HEX. Also, the keyboard interrupt is jumper selected to generate a level 2 interrupt to the main CPU card. For additional information on the Video RAM Card, refer to the DATACUBE VR-107 Data Sheet and VR-107 Programmer's Reference Manual.

2.2.1.9 RAM/ROM and Expansion I/O Card

An Intel iSBC 116 Combination Memory and I/O Expansion Board is used in the ALWOS system to provide both additional RAM/ROM memory and to increase tne system's input-output capability. Each iSBC 116 offers 16k bytes of RAM (read/write) memory and sockets for up to 8k bytes of ROM (read only) memory. It interfaces directly with the main CPU card via the system bus and provides 48 programmable I/O lines as well as a synchronous/asynchronous RS-232 communications interface. In the ALWOS configuration, the iSBC 116 card provides the system an additional parallel input for the back-up cnannel of the remote analog to digital converter system (Remote A/D #2). The 16-bit parallel data is received at the same rate and format as tnat of Remote A/D #1 but generates a level 5 interrupt request to the main CPU card for each 16-bit word transferred. The iSBC RAM and ROM memory provide tne main CPU card additional temporary storage locations as well as increased fixed program area, respectively. RAM memory on the iSBC 116 card is jumper selected to begin at address 8000 HEX and continue through BFFF HEX. ROM memory is jumper selected to begin at 2000 HEX and continue through 3FFF HEX. For more detailed technical data on this card, refer to tne Intel iSBC 116 Hardware Reference Manual. Also, refer to section 2.3 for additional information on the Remote Analog to Digital Converter System.

2.3 Remote Analog to Digital Converter System

The remote analog to digital converter system is used to digitize the ALWOS analog sensor outputs located at Dulles Airport centerfield and to transmit the informtion back to the ALWOS computer chassis for processing. Due to the estimated half mile or longer cable run between the centerfield sensor site and the ALWOS

processor located in the Dulles WSO building, it was decided to digitize the analog signals at the centerfield site. The remote A/D system used in the ALWOS test was supplied by FAA's Transportation System Center (TSC) and a block diagram of the system is shown in figure 2-11.

ALWOS REMOTE ANALOG TO DIGITAL CONVERTER SYSTEM

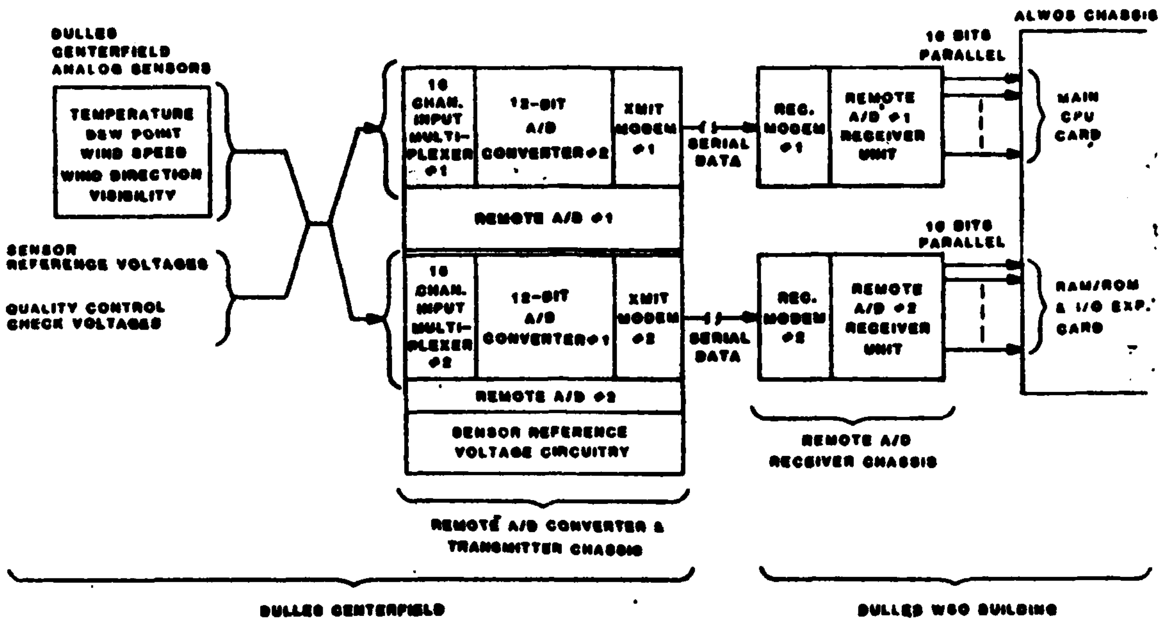


FIG. 2-11

Analog outputs from the temperature, dew point, wind speed, wind direction, and visibility sensors, as well as reference voltages, are connected to the co-located remote A/D system through assigned channels of the input multiplexer and are listed in Section 3.4 Sensor Data Conversion and Processing. Each input to the remote A/D system is actually connected in parallel to a second or back-up A/D converter system. In the block diagram and elsewhere in this text, the main A/D system and its identical back-up A/D system are referred to as remote A/D #1 and remote A/D #2, respectively. Sensor inputs to the 16 channel input multiplexer are scanned sequentially at a 160 Hz.rate (10 updates per second for a given parameter) and digited by the A/D converter module. The digitized data is then transmitted in a bit serial format by modem over cable pair back to the WSO building where the data is received by a similar modem, assembled into a parallel format and presented to an I/O port on either the main CPU or RAM/ROM & Expansion I/O card. A/D conversion and transmission of the sensor data to the ALWOS processor is done continuously by both systems. Parallel data is formatted in a 16 bit word where the most significant 4 bits represent the channel number (0-15) and the least significant 12 bits contain the digitized voltage (1.221 millivolts/bit). For additional information on the remote A/D converter system, refer to Sections 3.2.2 Interrupt Handlers and 3.3 Sensor Data Collection.

Processed data is output from the ALWOS system to a local printer, local CRT display, remote CRT display, remote voice output and remote telephone dial-up. A local cassette recorder was also part of the original system output but was removed when its operation became erratic.

The local printer, Texas Instruments' model 745, operates at 300 baud and prints a one minute observation message every 20 minutes. An example of its printout and explanation of each parameter is shown below.

IAD ALWOS 09/04 1800 09 SCT E13 BKN 3 P 69/66/2603/009

IAD ALWOS	- Dulles Airport & ALWOS identifiers
09/04 1800	- Month, Day, and Greenwich Mean Time of observation
09 SCT	- Scattered cloud layer at 900 feet
E13 BKN	- Broken ceiling layer at 1300 feet. E (estimated) is inserted before 1st ceiling layer to signify that a single sensor is used to measure sky conditions.
3	- Visibility of 3 miles
P	- Precipitation detected
69/66	- Temperature/Dew Point (°F)
2603	- Wind Direction 260° and wind speed of 3 knots
009	- Altimeter setting 30.09 inches of mercury

The local printer and the remote telephone dial-up receive data from the same storage buffer of the ALWOS Output card. The one minute observation, stored at 00, 20 and 40 minutes after the hour, is transmitted to both the local printer and the remote telephone dial-up whenever the telephone interfaced is polled, nominally at 10, 30 and 50 minutes after the hour. If the telephone is not polled in the 20 minutes interval, the software forces the data to be transmitted to tne local printer at 19, 39 and 59 minutes after the hour. A status word, described in Section 3.9 Accounting, would have appeared at the end of the message if the system had detected any recent errors within the system.

The voice output speaker is located on the 11th floor of the Dulles Airport tower adjacent to the remote CRT display where both ALWOS outputs are available to FAA personnel for evaluation.

Voice messages are updated and output every minute and are essentially a spoken version of the ALWOS one-minute observation.

Previous automated tests have demonstrated that these voice messages can successfully be transmitted to nearby pilots via radio link for an up-to-date weather observation while enroute. A cassette recording of the ALWOS voice output is included as a separate deliverable.

The remote CRT receives its data in an ASCII serial format at 300 baud and displays a new ALWOS observation every minute. When a new observation is received and displayed at the bottom of the CRT, the previous one-minute observations are scrolled up such that the previous 11 observations are displayed.

The local CRT or maintenance display is an integral part of the ALWOS MB80 chassis and is programmed to offer four different display modes under keyboard control: normal, observation, accounting and maintenance. The normal display mode includes only the month, day and Greenwich Mean Time (GMT) information at the top of the screen with a CPU idle time percentage displayed in the upper right corner. The nearly-blank screen is used in normal operation during the test period at Dulles to prevent any biasing of the Dulles observers by the ALWOS observation. This mode is selected whenever the system has been powered up, rebooted, or the "RSTR" (restart) key is depressed.

The local CRT's observation mode displays several of the sensors' one-minute averages in the upper half of the display as well as the system's formatted output message in the bottom half(figure 2-12). This mode is entered from the normal mode by depressing the "CTRL" (control), "~", and "SHIFT" keys simultaneously.

```
        0 9 : 1 5 : 1 3 : 4 3 : 2 8                     9 1

   T E M P E R A T U R E      7 2   D E W P O I N T      6 8

   W I N D  D I R             3 6   P R E S S U R E  2 9 5 1 3

            S P E E D           4                    2 9 5 1 3

            P E A K             5   V I S I B I L I T Y    3

  3    P B 0 1 E 2 0

7 2 / 6 7 / 3 6 0 4 / 9 8 6

  C L R   B L 0   3 0
```

Local Display in Observation Mode

Figure 2-12

(Note- The '91' in the upper right corner of the display represents the main CPU's idle time percentage for the previous second. In other words, the processor was idling 91 percent of the time during the 27th second after the minute. This number decreases appreciably at 10 second intervals and on the minute when the processor has a greater workload.)

The accounting mode, entered from either the normal or observation mode by depressing the "ACCT" key, displays on the bottom half of the local CRT errors that the system has detected for each parameter during the last hour and 24 hour periods. This mode also displays the date and time (Greenwich) of the last total system restart due to power up, resetting the system clock or rebooting the system through the front panel switch. The top half of the display will also contain the observation mode data if the accounting mode was entered following the observation mode. This sequence is shown in figure 2-13. The displayed accounting data is updated only when the "ACCT" key is depressed.

```
    09:15:13:25:57                  91

  TEMPERATURE    72  DEWPOINT    68
  WIND DIR        0  PRESSURE 29513
       SPEED      0           29513
       PEAK       3  VISIBILITY   3

 3 PB01
72/68/0000/986
 CLR BLO 30
```

SENSOR	LAST HOUR	FROM HR 0	SENSOR	LAST HOUR	FROM HR 0
TEMP	0	0	CAL	0	0
DEWPT	0	0	VIS	0	0
WIND SPD	0	0	INAD	0	0
WIND DIR	0	0	RAD1	0	1
PR1	0	0	RAD2	0	1
PR2	0	0			

POWER UP TIME 9: 9:13:16:47

Local Display in Accounting Mode

Figure 2-13

(Note: System has detected one error in Remote A/D #1 (RAD1) and Remote A/D #2 (RAD2) since 9/15 00 hours GMT)

The maintenance mode on the local CRT is entered from the normal or observation modes by depressing either the "MNT/1 SEC", "MNT/5 SEC" or "MNT/DMD" keys. Maintenance data are then displayed on the lower half of the CRT and updated every second, every 5 seconds or upon keystroke demand, respectively. Remote digital data, representing the 16 channels of digitized voltages from the selected remote A/D converter system, are displayed as well as digital pressure values and offsets converted by the local A/D converter card. The actual sensor voltages can be obtained for analysis by multiplying the digitized values by 1.221 millivolts per bit. The format of the ALWOS display in the maintenance mode (following an observation mode) is shown in figure 2-14.

```
     09:15:13:29:57                  91

  TEMPERATURE     72  DEWPOINT     69
  WIND DIR        35  PRESSURE 29513
       SPEED       3               29513
       PEAK        4  VISIBILITY    3

 3 PB01
72/68/3503/986
 CLR BLO 30

CHANNEL     DATA      CHANNEL     DATA
   0        1241         1         617            PRESSURE #1   3277
   2          68         3           0            OFFSET #1       86
   4          24         5        3831
   6        1102         7        1628            PRESSURE #2   3277
   8        4095         9        2638            OFFSET #2      119
  10        1971        11        1929
  12        2048        13         820            CALIBRATION   2734
  14         182        15           0

            REMOTE A/D #1
```

Local Display in Maintenance Mode

Figure 2-14

The remote A/D channel assignments are found in section 3.4 Sensor Data Conversion and Processing.

2.5 Hardware Cost Analysis

The cost of the ALWOS system's component parts, as purchased in 1979, are shown in figure 2-15. As stated earlier in this document, the cost of the ceilometer and visibility sensors far exceed the cumulative cost of the remaining sensors and processing equipment. When our prototype laser ceilometer was originally purchased in 1979, its price was $47,000. A 1981 purchase of a similar ceilometer, also from Impulsphysik, was priced at $25,000 and hopefully indicates that the cost of this type of ceilometer will drop as the technology becomes further developed. Also, the cost (and the size) of the data processing equipment necessary for an automatic weather observation station has continued to decrease. In 1974, when the AV-AWOS minicomputer system was purchased, the data processing equipment necessary to perform that task cost approximately $60,000 and required two 19" wide by 6 feet tall racks to hold the equipment. Conversely, the ALWOS processing equipment cost approximately $9,000 in 1979 and fits into a desk top chassis.

ALWOS SYSTEM COMPONENTS' COST (AS TESTED AT DULLES AIRPORT)

1.	MB80 Microcomputer Chassis - includes 80-20/4 CPU & Video Ram Cards	$ 3,600
	Additional Cards:	
a)	iSBC 80-20/4 CPU board (included in item #1 price - $865)	
b)	iSBC 80-20/4 CPU board (2nd)/Ceilometer CPU	865
c)	Intel A/D board iSBC 711	1,180
d)	STC VOICE board	860
e)	Intel RAM/ROM board iSBC 116	1,035
f)	Canada Sys. RTC board	425
g)	Data Cube Video RAM board (included in item #1 price - $540)	
h)	EDL Sensor Input board	300
i)	EDL Output board	700
	MICROCOMPUTER CHASSIS AND PROCESSING CARDS SUBTOTAL (Note: Intel Prices as of October '79/1-9 units)	$ 8,965
	SENSORS:	
2.	Ceilometer - Impulsphysik Mod 157.101.002 S/N 01/1 (Unit purchase @ $47,000 with production est.@ $30,000)	47,000
3.	Visibility - Forward Scatter Meter EG&G Mod. 207.	12,000(est.)
4.	Temperature - Gill Aspirated Unit (includes temperature and dewpoint)	1,000
5.	Dewpoint - " " "	
6.	Wind Speed - RAMOS	400
7.	Wind Direction - RAMOS	400
8.	Precipitation Yes/No - Science Assoc./ Wong Laboratories Mod.598-2.	300
9.	Thunderstorm - Atlantic Scientific Corporation Mod. FCM-1	900
10.	Pressure/Alt.Setting - Garrett/Air Research Div.,Two / System @ $1200 ea.	2,400
	SENSOR SUBTOTAL	$64,400
	OUTPUT PERIPHERALS:	
11.	Local Printer - Texas Instruments Mod. 745	1,500
12.	Remote CRT Display - Telray CRT Monitor Mod.3511D	1,000(est.)
	PERIPHERAL SUBTOTAL	$ 2,500
	ALWOS SYSTEM TOTAL	$75,865 *

*(Does not include cost of Rem. A/D System - GFE'd by FAA's TSC group.)

Figure 2-15

3. SOFTWARE CONFIGURATION

SYSTEM OVERVIEW

The Automatic Lowcost Weather Observation System (ALWOS) is a real-time, interrupt driven, microprocessor resident meterological data collection and reporting system. Running under the control of a time scheduling executive, ALWOS periodically acquires data from various sensors and a separate CPU, collecting and processing cloud height and ceiling data. It processes these data, performs quality control checks, and provides communication sources to transmit and display the information.

The software system is a highly modular, flexible system, making extensive use of tables for scheduling. The modularity and tabling structure will allow the system to accept most of the existing inventory and newly developed sensors. Modules may be easily modified, replaced or adde for tailored configurations.

The software system is functionally separated into nine components: data structure, the executive, sensor data collection, sensor data conversion and processing, keyboard processor, data display/communications, quality controller, maintenance, and accounting. Each of these components is described below.

3.1 DATA STRUCTURE

Data storage and executive tables are defined in specific areas of Random Access Memory (RAM) and Read Only Memory (ROM). The ROM tables are defined from absolute location 3C00H 'ROMTBL'. Tables residing there, their organization and contents are defined as follows:

RTA- Timed routine jump table. An expandable table currently containing 42 entries. Each entry requires 6 words, and is comprised of a subroutine call followed by a jump to SCAN instruction. There is one entry for each of the timed modules currently in the system. The table is used to transfer control to the module which SCAN determines is to be executed, and return control to SCAN following execution.

SFKTBL- Special function key jump table. Table of 28 entries corresponding to the 28 special function keys on the keyboard. Each entry requires 6 words and contains a subroutine call,(to respond to the function key) followed by a jump to KBEND (keyboard interrupt service routine entry point to restore interrupts and return from the interrupt). The table is organized so that entries sequentially correspond to function key ASCII codes (81H-9AH). Currently only 10 keys are used.

CTRTBL- Cursor control table. Table of 7 entries corresponding to seven cursor control functions: left, right, down, up, erase, carriage return-line feed, and home. Each entry requires 6 words and consists of a subroutine call followed by a jump to KBEND, (return to the keyboard interrupt handler).

DETBL- Data entry mode table. This table is an expandable table currently consisting of 3 entries corresponding to 3 keyboard input modes. Each entry is 6 words long, consisting of a subroutine call followed by a jump to KBEND, (return to keyboard interrupt handler). An input mode software flag word, 'KYMODE', may be set (0,1.2,3) and used by the keyboard interrupt handler to dispatch through this table for data input. KYMODE=0 is the normal mode and does not use this table, data and text keys are only echoed by the interrupt handler. KYMODE=1 is currently used to set the real-time clock, (subroutine 'STDATA'), modes 2 and 3 are not used.

JTBL- Programmable Interrupt Controller interrupt vector jump table. This table is absolutely defined beginning at 3FC0H. It contains 8 entries, each 4 bytes long corresponding to the 8 hardware interrupt levels. Interrupts are hardware vectored to the appropiate level entry in the table. Each entry consists of a jump instruction (jump to the interrupt service routine) followed by a no-operation instruction to occupy the 4th byte.

A designated block of RAM memory is defined at 7200H. This expandable block is currently 394H words long, and is used for all system storage with the exception of some temporary internal storage required by certain modules. Volatile system tables and all data buffers required by the system are defined here. Data buffers will be described as they are referenced by individual modules.

TTA- Scheduled module time table. This expandable table currently contains 42 entries. Each entry requires 6 words. The table is organized to correspond directly to the timed routine jump table (RTA) in ROM. Each entry contains month, day, hour, minute, second, and a year flag. The entry specifies the exact time the corresponding routine in the RTA table is to be executed by SCAN. The times are cleared and must be reset following each execution of the routine.

3.2 EXECUTIVE

The executive which controls the ALWOS operation consists of three functional components: initialization/restart-recovery, interrupt handlers, and module execution controller (SCAN).

3.2.1 INITIALIZATION/RESTART-RECOVERY

During initialization, automatic recovery following a power failure, or after resetting the real-time clock, the following functions are performed in module 'INIT': all data areas in volatile memory (RAM) are cleared; the interrupt controller, CPU stack, video-ram, keyboard, real-time clock, event sensor port, and remote A/D's are initialized; the video-ram display area is cleared; the real-time clock is started and the

power-up time recorded; site dependent variables are defined; a block of buffers in RAM used to form averages by the various processing programs is initialized to OFFH; modules that are to be executed periodically by SCAN are initially scheduled for execution by inserting the execution times in the 'TTA' table; int rrupts are enabled to start the data collection functions; and CPU control is transferred to the execution controller (SCAN). The 'INIT' module is an absolute module starting at location 0.

3.2.2 INTERRUPT HANDLERS

The interrupt handler section of the executive reacts to hardware interrupts from the system peripherals. The Programmable Interrupt Controller directs CPU control to a specified memory location determined by the interrupt level (0-7). The predefined locations in 'JTBL' contain instructions which vector CPU control to the appropiate interrupt service module .

The system currently accepts interrupt levels 2, (keyboard); 3, (serial characters received from ceilometer CPU card); 4, (remote A/D #1); 5, (remote A/D #2); 6, (real-time clock) ; and 7, (low-voltage detect). Each interrupt handler (except level 7) independently saves and restores the state of the system while servicing an interrupt and enables interrupts following execution. Level 7 interrupts, or low voltage detections, force the system to halt execution before erratic system behaviour can begin. Interrupts occurring at levels other than those specified above are handled by an interrupt error service routine.

Keyboard- The keyboard interrupt handler ,'KEY'. reads and identifies each keystroke and responds by either scheduling a module for execution, calling a subroutine, or performing a specific function. The response depends on the hexidecimal code generated by the key and the keyboard input mode selected at the time of the interrupt. ROM tables 'SFKTBL', 'CTRTBL', and 'DETBL' are used to determine the proper response to the various key codes. The keyboard input mode causes a routine called in table 'DETBL' to be executed for data and text keys, special function keys cause the appropiate routine in 'SFKTBL' to be executed and the cursor control keys are handled through table 'CTRTBL'. Selection of which routine, in the proper table, to execute is based on an offset into the table determined by the hexidecimal code generated by each key.

Ceilometer Characters- For each character that is received over the serial input port, a level 3 interrupt is generated. "CEILIN" handles the ceilometer message input character interrupts then reads and stores the ceilometer message in RAM buffer 'CEILUP'. After receiving the end of message character, "CEILIN" schedules "CEILMO" for execution to move the ceilometer message from the interrupt buffer(CEILUP) to the processing buffer(CEILCU).

Remote A/D #1 and #2- For each interrupt the A/D handlers read the data from ports A and B, identify the channel(0-15), store

the data in a cycling buffer and reset the interrupt control. This is a continuous process, running at the conversion speed of the remote A/D's. Remote A/D #1 interrupt handler, 'ADEXT', stores data in RAM buffer 'RADTB'. The A/D #2 handler, 'AD2EX', uses RAM buffer 'RAD2B'. Each buffer is 32 words long, with 2 sequential 8-bit words used for each A/D channel of data. The most significant 4 bits are a channel number, (0-15), and the least significant 12 bits contain the digitized voltage (1.221 millivolts/bit).

Real-time clock- The R/T clock interrupt handler, 'RTC', is executed once/second. It reads and saves the clock time, verifys that the clock has incremented, and calls a subroutine to display the new time. Clock time is stored in a 5 byte RAM buffer, 'CMT', (month,day,hour,minute,second), and displayed by subroutine 'DISCMT'. The subroutine also stores the ASCII equivalents (MM/DD) in 'DATASC',(5 bytes), and (HHMM) in 'TIMASC', (4 bytes).

Low-voltage detect- A level 7 interrupt is generated whenever a low voltage condition is detected and forces the CPU to execute a HALT instruction and cease operation. When power is restored the system will execute a complete re-initialization before normal operation is begun.

Interrupt errors- The interrupt error handler, 'INTERR', handles interrupts at any other level (0,1). These result in an error message indicating the interrupting level. The interrupt is cleared and system execution continues normally.

3.2.3 MODULE EXECUTION CONTROLLER (SCAN)

The SCAN function of the executive is active when no initialization, data processing or interrupt handling is occurring. This function activates all timed modules in the system. It is activated during initialization and continues to cycle each second, interrupted only to execute a timed out module or for hardware interrupt service. SCAN interrogates a table of start times ,'TTA', associated with all time dependent modules. The modules are priority ordered to assure the highest priority module is executed first. The start time for each module is compared to the current clock time until a greater-than or equal-to match is found. CPU control is then transferred to this module through ROM table 'RTA', and its start time is removed from the SCAN table. Following module execution, the module is responsible for rescheduling itself by inserting a new start time in the SCAN table. CPU control then returns to SCAN and the scanning process continues from the beginning of the SCAN table. If during a one second scan, the scanning process reaches the end of the SCAN table, control is passed to an idle timer, which displays, at the beginning of the next second, the percentage of time that the system was idle. The next one second real-time clock interrupt causes control to restart the SCAN sequence.

3.3. SENSOR DATA COLLECTION

Sensor data is collected using the external A/D interrupt

handlers, interrogation of the internal A/D, 'ADDATA', and communication with the ceilometer CPU through external serial I/O using character interrupts. A module, 'XADT', is executed each second which checks reference voltages for both remote A/D's and transfers an A/D buffer of data (16 channels from one of the A/D's) into a 1 second raw data buffer in RAM, ('ADTBL', 32 words). These input data are used as the 1 second samples to be processed over the next second. Pressure data are obtained from the internal A/D through interrogation by the scheduled pressure conversion modules at a 10 second rate. Approximately every four minutes, the processed ceilometer message is received from the ceilometer CPU card and placed in buffer 'CEILCU' for processing. The message is prepared by the ceilometer CPU operating independently of the main CPU.

3.4. SENSOR DATA CONVERSION AND PROCESSING

Conversion and processing of data occurs in a series of scheduled modules for each parameter. The modularity of the system is preserved in most cases by validating and converting data to sensor independent units in one module and performing the processing algorithm in seperate modules. Each parameter is processed by a module or group of modules. The modules are scheduled to execute at intervals required by the parameters algorithm. The following table lists each module by name and function, specifies its primary outputs in RAM, and any special scheduling considerations.

XADT-Remote A/D's self-checking and acquisition.
Execution- 1/second prior to any other processing module.
Outputs- 'ADTBL', buffer containing 32 words. (16 channels of data, bits 0-3= channel number (0-15), bits 4-15= digitized voltage, 1.221 millivolts/bit).

Contents of A/D channels for remote A/D #1 and #2.

Channel #	Contents
0	Temperature
1	Dew Point
2	Visibility +log voltage
3	Visibility -log voltage
4	Wind Speed
5	Wind Direction, Tap A voltage
6	Wind Direction, Tap B voltage
7	Wind Direction, Tap C voltage
8	5v Wind Direction reference, nominal 5.0vdc
9	Temperature reference, nominal 3.219vdc
10	Dew Point reference, nominal 2.404vdc
11	19v reference for multiplexer, nominal 2.5vdc
12	5v power supply, nominal 2.5vdc
13	+/-15v reference, nominal 1.0vdc
14	Hoffman box cooling fan sensor
15	Ground reference

WS- Wind speed acquisition and processing.
Execution- 1/second.
Outputs- 'WS1AVG'-1 word, wind speed 1 min. average (knots).

'WSCUR'- 1 word, current wind speed (knots).
'WS1ASC'- 5 word buffer, 1 minute average wind speed (ASCII, knots).

WD- Wind direction acquisition.
Execution- 1/second.
Outputs- 'WD1AVG'- 1 word, current running 1 minute wind direction average (degrees, scaled 255/360).

TUNDER- Event sensor acquisition and thunderstorm detection.
Execution- 1/second before 'LITEN' or 'PRECIP'.
Outputs- 'EVENT'- 1 word, event sensor word where:

bit	0	1	2	3	4	5	6	7
	1	ZR	T	R	1	1	1	D/N

Bit=1 for ZR,T,R indicates event present
(Bit #7 : 0=Day, 1=Night)
Bits 0,4,5,6 not used.
'TUNFLG'- 1 word, flag indicating presence or absence of lightning activity and timing elapsed since last strike.

TMP- Temperature acquisition, quality control and conversion.
Execution- 1/second.
Outputs- 'T1AVG'- 1 word, current 1 minute temperature average (^{o}F.).
'TMPCUR'- 1 word, current temperature (^{o}F.).
'T1ASC'- 5 word buffer, current 1 minute temperature average (ASCII ^{o}F.).
'TMPFLG'- 1 word, temperature error flag.

DPT- Dew point acquisition, quality control and conversion.
Execution- 1/second.
Outputs- 'DP1AVG'- 1 word, current 1 minute dew point average (^{o}F.).
'DPTCUR'- 1 word, current dew point (^{o}F.).
'DP1ASC'- 5 word buffer, current 1 minute dew point average (ASCII ^{o}F.).
'DP1FLG'- 1 word, dew point error flag.

CALINT- Pressure sensors calibration check.
Execution- Each 10 seconds.
Output- Console message if calibration bad.
Calibration data is acquired by 'CALINT' from the internal A/D, Intel SBC 711 analog input board, through subroutine 'ADDATA'. It reads the calibration voltage, (nominal 3.333v) from channel 13 of the A/D, (12 bits, 1.221 millivolts/bit).

PRSAQ1- Pressure sensor #1 and offset #1 acquisition and conversion.
Execution- Each 10 seconds.
Outputs- Entry in 'PRS1OF', 12 word buffer of converted 10 second pressure readings (16 bits per data entry in in. of Hg.).
Data is acquired through subroutine 'ADDATA', pressure sensor #1 read on channel 3, (12 bits), offset voltage on channel 15 (12 bits). each has a resolution of 1.221 millivolts/bit.

PRSAQ2- Pressure sensor #2 and offset #2 acquisition and conversion.

Execution- Each 10 seconds.
Outputs- Entry in 'PRS2OF', 12 word buffer of converted 10 second pressure readings (16 bits per data entry in in. of Hg.).
Data read by subroutine 'ADDATA', pressure sensor #2 on channel 4, (12 bits), offset voltage on channel 14, (12 bits), 1.221 millivolts/bit for each.

VISACQ- Acquisition, quality control and conversion of Visibility.
Execution- Each 10 seconds.
Outputs- Entry in 'VISABF', 12 word buffer of 10 second visibilities, (16 bits per entry).
'VIZNO'- 1 word visibility noise counter.

TEMP- Temperature processing.
Execution- 1/minute after 'TMP'.
Outputs-'T5AVG'- 1 word, 5 minute temperature average(°F.)
'TMPMAX'- 1 word, 5 minute average temperature maximum.
'TMPMIN'- 1 word, 5 minute average temperature minimum.
'T5ASC'- 5 word buffer, 5 minute temperature average (ASCII °F.).

DEWPT- Dew point processing.
Execution- 1/minute after 'TEMP' and "DPT'.
Outputs- 'DP5AVG'- 1 word, 5 minute dew point average (°F.).
'DP5ASC'- 5 word buffer, 5 minute dew point average (ASCII °F.).
'DPTC'- 1 word, dew point error count.

WNDSPD- 10 minute wind speed processing.
Execution- 1/minute after 'WS'.
Outputs- 'WS10AV'- 1 word, 10 minute wind speed average (knots).
'WS10AS'- 5 word buffer, 10 minute wind speed average (ASCII knots).

GUST- determine 10 minute maximum wind speed gust and peak wind.
Execution- 1/minute after 'WNDSPD'.
Outputs- 'GSTCUR'- 1 word, current maximum gust (knots).
'GSTASC'- 5 word buffer, current maximum gust (ASCII knots).
'PKWASC'- 5 word buffer, current peak wind (ASCII knots).

WNDDIR- 1 minute wind direction quality control and processing.
Execution- 1/minute after 'WD' and 'WNDSPD'.
Outputs-'WD1AVG'-1 word,1 minute wind direction average(°)
'WD1ASC'- 5 word buffer, 1 minute wind direction average (ASCII 10's of °).
'WDMASC'- 5 word buffer, 1 minute magnetic wind direction (ASCII 10's of °).
'WDCNT'- wind direction error count.

PRSPC1- Station pressure and altimeter setting calculations.
Execution- 1/minute after 'PRSAQ1' and 'PRSAQ2'.
Outputs-'PR1ASC' 5 word buffer, ASCII station press. #1 in.Hg.

'PR2ASC'- 5 word buffer, ASCII station pressure #2 (inches Hg.).
'ALTASC'- 5 word buffer, ASCII altimeter setting.
'PR1CUR'- 2 words, current station pressure (inches Hg.).
'PR2CUR'- 2 words, current station pressure #2 (inches Hg.).

VIZ- Sensor equivalent visibility (SEV) processing.
Execution- 1/minute after 'VISACQ'.
Outputs- 'VIZCUR'- 2 words, current SEV (miles).
'VIZER'- 1 word, count of visibility failures.
'VZAS'- 1 word, visibility table offset for ceilometer CPU.
'VIZOFF'- 1 word, visibility table offset for 'VOICE' output.
'VIZASC'- 4 word buffer, current 10 minute average SEV (ASCII miles).
'PVASC'- 16 word buffer, visibility variability remark, (ASCII), word 1 of buffer= # ASCII characters in remark.

VISIBILITY FLAGS - Two visibility flags are passed to the Ceilometer CPU card in parallel through port E5H on the main CPU card:

bit 6 = 1 means that visibility is missing
bit 7 = 1 means that visibility value is less than or equal to 1.5 miles. (bit 7 = 0 means visib.greater than 1.5 miles) If visibility is missing, then the ceilometer processed output will be reported missing. The ceilometer card uses the visibility value less than or equal to 1.5 miles to determine possible obscuration conditions.

LITEN- Thunderstorm event processing.
Execution- 1/minute after 'TUNDER'.
Outputs- 'TRMASC'- 7 word buffer, thunderstorm beginning or ending remark (ASCII).

PRECIP- Precipitation event processing.
Execution- 1/minute after 'TUNDER'.
Outputs- 'RASC'- 7 word buffer, precipitation beginning or ending remarks buffer. (ASCII).

3.5. KEYBOARD PROCESSOR

The keyboard processor handles all manual entry of standard and special function keys. Software components are scheduled or called as subroutines by the keyboard interrupt handler to provide special displays for maintenance and accounting, clear displays, set the real-time clock, initialize the system, and respond to other specific function keys. Subroutines called by 'KEY' through ROM tables 'SFKTBL', 'CTRTBL', and 'DETBL' to handle the keyboard processing are listed and discussed in the 'ROMTBL' module listing.

3.6. DATA DISPLAY/COMMUNICATIONS

The display processor functions are performed by several modules which handle the assembly and output of information to the CRT's and transmission of separate messages to cassette, telephone and voice outputs. Modules are scheduled at regular intervals for display and transmission, or on demand as the

result of special function keystrokes for the maintenance and accounting displays. The following table lists normal output modules by name and function, lists primary input and output, and special scheduling considerations.

CRTOUT- Assemble and output 1 minute message data to the remote CRT display.
Execution- 1/minute following all processing modules.
Input- ASCII buffers in RAM containing the processed data to be output:
'DATASC', 'TIMASC', 'RASC'. 'TRMASC', 'VIZASC', 'T5ASC' 'DP5ASC', 'WD1ASC', 'WS1ASC', 'GSTASC', 'ALTASC', and 'CEILCU'.
Output- 'HDRBUF'- 23 word buffer containing station header and time of message (ASCII). First byte of buffer contains the # of ASCII characters (bytes) in the buffer (hexidecimal).
'RBCASC'- 20 word buffer containing the ceiling remarks generated by the Ceilometer CPU, (ASCII). First byte= # ASCII bytes in buffer, (hexadecimal).
'CRTBUF'- 60 word buffer containing the assembled data message, a composite of ASCII input buffers, (ASCII). First byte= # ASCII bytes (hexidecimal).
Contents of the output buffers are also output to the Output board for display on the remote CRT.

VOICE- Output 1 minute message to the Voice output board in the form of vocabulary addresses for spoken output.
Execution- 1/minute after 'CRTOUT'.
Input- ASCII buffers in RAM containing data to be broadcast.
ASCII buffers: 'T5ASC', 'DP5ASC', 'WS1ASC', 'WDMASC', 'GSTASC', 'ALTASC'. 'TRMASC', 'RASC', 'TIMASC', 'RBCASC', and 'VIZOFF'- 1 word offset pointer to the visibility in 'VSLST', the visibility vocabulary table.
Output- vocabulary addresses to the speech output board hardware.

CASOUT- Output 1 minute message to the cassette and telephone line.
Execution- Each 19 and 20 minutes after 'CRTOUT'.
Input- ASCII message buffers: 'HDRBUF', 'CRTBUF', and 'RBCASC'.
Output- ASCII characters to the FIFO on the Output board.
'FALASC'- 5 word buffer, the error status word (ASCII).

3.7. QUALITY CONTROL

Quality control checks are applied at two levels. During the data acquisition, on reference and calibration voltages, as a self-check of the equipment, and during conversion and processing phases for integrity, range extremes, and parameter rate of change. All failures are recorded in the accounting section and appropriate indications are given in the form of error messages and missing data in the system outputs.

An error status word buffer, 'FALASC', is generated in 'CASOUT' and output to the cassette and telephone, (see 3.9 ACCOUNTING.

3.8. MAINTENANCE

Data input into the system may be monitored at the raw data and processed data levels through a maintenance display available at the system console initiated by a special function key. The display shows the digitized voltages from the remote and internal A/D's as well as the processed data. The display may be updated at a 1 or 5 second rate or on demand from the keyboard. Input data from either remote A/D may be selected, via the keyboard.

DISEXA- Display raw input data on the console CRT.
Execution- Selected via a special function key, once selected, executes once per second, once per 5 seconds or on demand. Scheduled for execution after 'XADT'.
Input- 'ADTBL'- 32 word buffer of remote A/D data.
Channels 3,4,13,14,15 of the internal A/D, read with 'ADDATA'.
'UAD'- 1 word indicating the remote A/D being used, 1=A/D #1, 2=A/D #2.
Output- Formatted display on the console CRT containing all the raw data input used by the system.

MINDSY- Display 1 minute output data on the console CRT for maintenance or monitor purposes.
Execution- Selected via a special keyboard code, control-shift-~. When selected, the module is scheduled to execute 1/minute after 'CRTOUT'.
Input- ASCII data buffers: 'T1ASC', 'DP1ASC', 'WS1ASC', 'WD1ASC', 'VIZASC', 'PR1ASC', 'PR2ASC', 'RBCASC', 'CRTBUF', and 'PVASC'.
Output- The data from the ASCII buffers is formatted and stored in Video-ram.

3.9. ACCOUNTING

The accounting software retains, and can display on demand, a history, since the last 0 hour, of the system status. The latest power-up time and the number of failures for each sensor and all A/D's in the last hour and for the last 24 hour period is available at all times in the system. A system status word, with one bit assigned to each sensor or A/D is extracted from the hour accounting data at 20 minute intervals, and is output as part of the cassette and telephone message. This status word indicates only recent and current failures within the system.
'FALASC'- A 5 word buffer containing the ASCII representation of the error status word. The error word is formed from 1-bit associations to the error counts in buffer 'TMPCNT', (see ERRHR). Bit 0= temperature,..., bit 11= remote A/D #2. Each non-zero bit indicates a corresponding non-zero error count for the sensor/device in 'TMPCNT'.

ERRHR- Accumulate 1 hour and since hour 0 counts of sensor errors and device failures in the system.
Execution- 1/hour after all collection and processing modules.

Input- 'TMPCNT'- 16 word buffer of 1 hour sensor and device error counts.

Word	Sensor/Device
1	Temperature
2	Dew point
3	Wind speed
4	Wind direction
5	Pressure sensor #1
6	Pressure sensor #2
7	Calibration voltage check
8	Visibility sensor
9	Internal A/D timeout check
10	Remote A/D #1 reference voltages
11	Remote A/D #2 reference voltages
12-16	Spares.

'TMP24'- 16 word buffer of summations of failures since last hour 0. The ordering of the buffer is identical to 'TMPCNT'.

ERRDSP- display accounting data on console CRT.

Execution- On demand by a special function key.

Input- 'TMPCNT'- 16 word buffer of 1 hour failure counts.

'TMP24'- 16 word buffer of failure counts since the last hour 0.

Outputs- A formatted display on the console CRT of error counts for the sensors and devices supplying input to the system.

3.10. UTILITIES

The system uses a number of general purpose utility routines which are called as subroutines by many of the modules in the system. Following is a list and brief description of utilities in the software system.

SCHED- Schedule a module for execution by inserting the current RTC time plus the indicated offset in the proper entry in ROM table 'TTA'.

SCH1M- Schedule a module for execution on the next whole minute.

SCH10- Schedule a module for execution at the next whole 10 second interval.

DISMSG- Output the designated ASCII message to the message display area of video-ram.

SCROLL- Scroll messages in the message display area of video-ram and blank the last line.

MCURS- Move the video-ram cursor as indicated.

ECHO- Echo an ASCII character to video-ram and move the cursor.

DELETE- Delete the character to the left of the video-ram cursor and move the cursor left one position.

MOVBYT- Move a number of bytes from one starting location to another. Move the last source byte first to allow overlaying blocks.

BINASD- Convert a 16-bit binary value to 5 byte ASCII decimal, left justified with leading zeros suppressed.

ASHEX- Convert 5 byte ASCII decimal to a 16 bit hexidecimal value.

CDRDH- Compare two CPU register pairs for greater-than, less-than, or equal .

SHFTLD- Shift a 16 bit CPU register pair left the specified number of bits.

DVI- Divide a 16 bit dividend by an 8 bit divisor.

PUSHWD- Push the designated block of words down 1 byte, last byte first. The last word is overwritten.

PUSHDN- Push the designated block of 16 bit values down 1 value. The last 2 bytes are overwritten.

AVG- Form the average of the indicated block of words.

AVGWD- Form the average of the indicated block of 16 bit values.

DIV- Divide a 16 bit dividend by a 16 bit divisor.

MULT- Multiply a 16 bit multiplicand by a 16 bit multiplier.

SUBT- Subtract two CPU register pairs (16 bits each) producing an absolute difference and indicating the proper sign.

COMP- Form the 1's complement of a 16 bit CPU register pair.

STANUM- Store a constant in a specified number of sequential RAM locations.

CRT- Transfer a string of ASCII characters into display memory. String is terminated by a null (0) character.

SHFTRD- Shift a CPU register pair right a given number of bits.

MOUT- Store 4 ASCII spaces and an ASCII 'M' in the designated 5 byte buffer.

3.11 MEMORY ALLOCATION

The ALWOS memory configuration is shown in figure 3-1. This memory space does not include the memory that is contained on the ceilometer CPU card. Its memory is accessed independently of the main system memory and is described in section 2.2.1.2 - Ceilometer CPU Card.

ALWOS MEMORY MAP

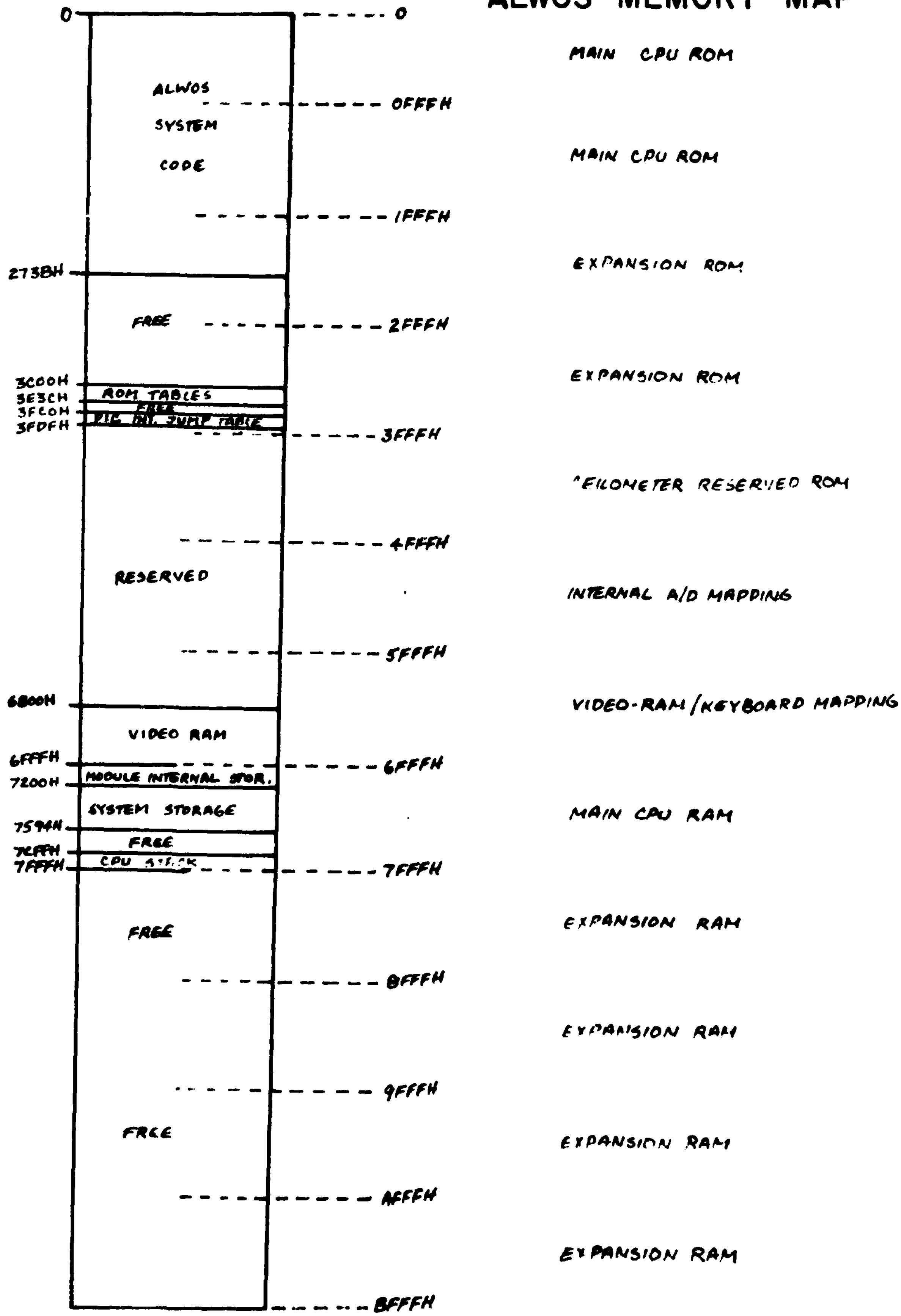
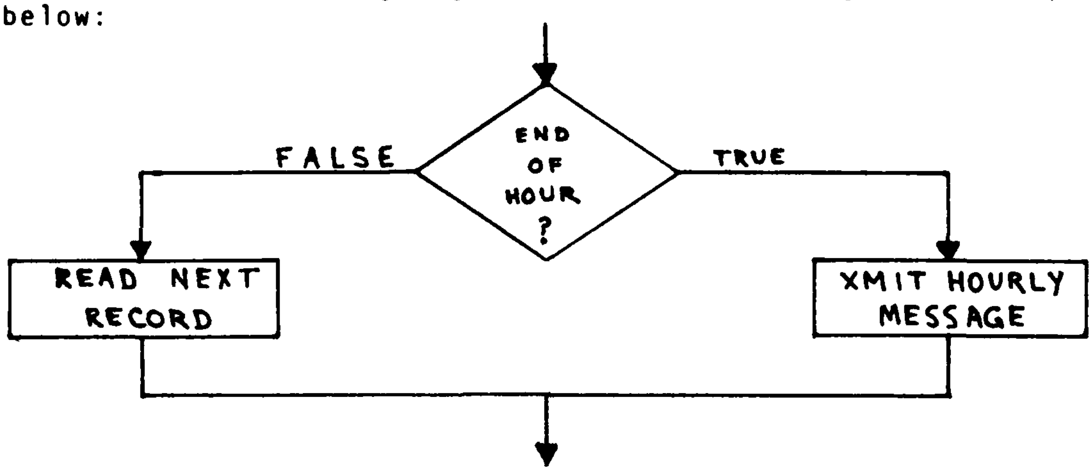


FIG. 3-1

3.12 SENSOR ALGORITHMS

The sensor algorithms contained in this section are described through the use of Program Design Language (PDL). PDL is an English language alternative to flowcharting methods in describing a processing algorithm. It offers a set of shorthand conventions for most common flowchart patterns, such as branches and loops of various kinds. For example, the following figure can be replaced by its PDL equivalent below:



PDL equivalent:

```
IF END OF HOUR
     THEN XMIT HOURLY MESSAGE
     ELSE READ NEXT RECORD
ENDIF
```

Each IF statement is matched against a corresponding ENDIF statement to signify the end of a test condition. Nesting of test conditions is also allowed . Corresponding indentations of the matching IF and ENDIF statements facilitates the decoding process. The "ELSE" statement is optional if it means simply to continue on to the following "ENDIF" statement. A more detailed analysis of PDL can be found in several of the structured program literature but is probably not necessary to understand the algorithms presented in this section. In addition to PDL, a hexadecimal notation is also used to describe the bit pattern of an 8-bit byte. Hexadecimal or "hex" implies that a numerical base of 16 is indicated rather than decimal or binary code. The use of this code is followed by the letter H. The equivalency between binary, decimal and hexadecimal codes is shown below. Each hex character then represents four bits or 2 hex characters for every 8-bit byte. An example of hex code would be 3FH which is equivalent to 0011 1111 in binary code. The hexadecimal code OFFH or FFH (leading 0 is optional) is often used in the following text to represent a -1 for flag words.

Binary	Decimal	Hexadecimal	Binary	Decimal	Hexadecimal
0000	0	0	1000	8	8
0001	1	1	1001	9	9
0010	2	2	1010	10	A
0011	3	3	1011	11	B
0100	4	4	1100	12	C
0101	5	5	1101	13	D
0110	6	6	1110	14	E
0111	7	7	1111	15	F

Other notations used in this section are:

.LT. = Less than .GT. = Greater than

.LE. = Less than or equal to .GE. = Greater than or equal to

The cloud and visibility algorithms are not presented in this section but can be found in Appendices A and B, respectively.

3.12.1 TEMPERATURE

The temperature data is processed by subroutines "TMP" and "TEMP".

TMP

Purpose: TMP performs temperature quality control and averaging. It is called once every 10 seconds.

Variable Names:

```
TMPFLG - ERROR FLAG  (ERROR = -1)
T1AVG  - TEMPERATURE 1- MIN AVERAGE
TMPCUR - CURRENT TEMPERATURE
T1ASC  - 1-MIN AVG TEMP ASCII BUFFER
TMPTBL - 1-MIN TEMPERATURE STACK
SCL    - SUBROUTINE TO CONVERT A/D VOLTAGES TO TEMPERATURE
```

Method:

```
PUSH DOWN ONE-MINUTE STACK
GET TEMPERATURE VOLTAGE FROM RAM
CONVERT VOLTAGE TO TEMPERATURE BY CALLING SCL
IF ((BEYOND VOLTAGE LIMITS) .OR. (TMP .GT. 122 DEG. F.).OR.
. (TMP.LT. -58 DEG F.) .OR. (1 MIN DIFF .GT. 6 DEG. F.))
. THEN IF (2ND ERROR IN 1 MINUTE)
.       . THEN SET ERROR FLAG
.       . INCREMENT ERROR COUNT
.       . SET DATA NOT AVAILABLE (-1 IN TMPCUR)
.       . SET AVERAGE NOT AVAILABLE (-1 IN T1AVG)
.       . SET ASCII M IN AVERAGE BUFFER
.       ENDIF
. ELSE IF (1ST ERROR OR LAST MINUTE MISSING)
.       . THEN SET DATA NOT AVAILABLE (-1 IN TMPCUR)
.       . SET AVERAGE NOT AVAILABLE (-1 IN T1AVG)
.       . SET ASCII M IN AVERAGE BUFFER
.       . ELSE STORE CURRENT TEMPERATURE IN RAM
.       . STORE CURRENT TEMPERATURE IN STACK
.       ENDIF
.       IF NOT 1 MIN OF GOOD DATA
.       . THEN SET AVERAGE NOT AVAILABLE
.       . SET ASCII M IN AVERAGE BUFFER
.       . ELSE TAKE SUM OF 1-MIN STACK
```

```
.       . DIVIDE TO TAKE AVERAGE
.       . STORE AVERAGE IN RAM
.       . CONVERT TO ASCII DECIMAL
.       . STORE IN ASCII BUFFER
.       . IF (ERROR FLAG .GT.0)
.       . . THEN RESET ERROR FLAG TO 0
.       . ENDIF
       ENDIF
ENDIF
RESCHEDULE IN TEN SECONDS
RETURN
END
```

TEMP

Purpose: TEMP calculates the five-minute temperature average and running maximum and minimum. It is called once each minute.

Variable Names:

```
 T5AVG  -  5-MIN TEMPERATURE AVERAGE
 T1AVG  -  1-MIN TEMPERATURE AVERAGE
 TMPMAX -  TEMPERATURE MAXIMUM
 TMPMIN -  TEMPERATURE MINIMUM
 T5ASC  -  5-MIN ASCII BUFFER
 T5TBL  -  5-MIN STACK
 TMPMN  -  ROUTINE NAME IN SCAN TABLE
 TMPC   -  10-SEC ERROR COUNT
 TMPCNT -  1-MIN ERROR COUNT
 TMPOK  -  TEMPERATURE OFFSET
```

Method:

```
PUSH 5-MINUTE STACK DOWN
IF (10-SEC ERROR COUNT.NE.0)
   THEN INCREMENT 1-MIN ERROR COUNT
ENDIF
CLEAR 10-SEC COUNT
GET 1-MIN AVERAGE
STORE AVERAGE OR OFFH IN STACK
IF (1-MIN AVG MISSING.OR.1ST 4 MIN.OR.NOT 5 MIN GOOD DATA)
   THEN SET 5-MIN AVG MISSING (-1 IN T5AVG)
        SET ASCII BUFFER TO M
   ELSE TAKE SUM OF 5-MIN STACK
        DIVIDE TO TAKE 5-MIN AVERAGE
        STORE AVERAGE IN T5AVG
        SUBTRACT TEMPERATURE OFFSET (99)
        CONVERT TO ASCII DECIMAL
        STORE IN ASCII BUFFER
        UPDATE MAXIMUM AND MINIMUM
ENDIF
RESCHEDULE FOR NEXT MINUTE
RETURN
END
```

ERROR PROCESSING:
IF THE 10-SEC ERROR COUNT IS NON-ZERO, THE 1-MIN ERROR COUNT IS INCREMENTED. IF THE 5-MIN AVERAGE IS MISSING, T5AVG IS SET TO -1, AND THE ASCII BUFFER T5ASC IS SET TO "M" (missing).

3.12 2 DEW POINT

Dew Point data is processed by subroutines "DPT" and "DEWPT".

DPT

Purpose: DPT performs dew point quality control and averaging. It is called once every 10 seconds.

Variable Names:

```
 ADTBL  - TABLE OF A/D CHANNEL VOLTAGES
 DPTSEC - ROUTINE NAME IN SCAN TABLE
 DP1AVG - 1-MIN AVERAGE
 DP1ASC - 1-MIN AVG ASCII BUFFER
 DPTCUR - CURRENT DPT
 DPTTBL - 1-MIN STACK
 VLTMIN - VOLTAGE MINIMUM
 VLTMAX - VOLTAGE MAXIMUM
 DPTOK  - DPT OFFSET
 DPTLST - DPT 1 MIN AGO
 ER2FLG - ERROR FLAG FOR LAST MINUTE
 DPTC   - ERROR COUNT
 SCL    - SUBROUTINE TO CONVERT A/D VOLTAGES TO TEMPERATURE (or DEW
          POINT)
```

Method:

```
PUSH 1-MINUTE STACK DOWN
GET VOLTAGE FROM RAM
CONVERT VOLTAGE TO DEW POINT BY CALLING SCL
IF ((TEMP MISSING).OR.(VOLTAGE LIMITS EXCEEDED).OR.
   (DP-TMP.GT.2).OR.(DP.LT.-40 DEG F).OR.(DP.GT.+90 DEG F)
   .OR.(1 MIN DIFFERENCE.GT.6 DEG F))
   THEN IF (2ND ERROR IN ONE MINUTE)
           THEN SET ERROR FLAG
        ENDIF
        INCREMENT ERROR COUNT
        SET 1-MIN ERROR FLAG (ER2FLG)
ENDIF
IF(DP-T.GT.0.AND.DP-T.LE.2)
  THEN SET DP=T
ENDIF
IF ((ERROR FLAG SET).OR.(1ST 10 SEC).OR.(FOLLOWING ERROR))
  THEN SET DATA NOT AVAILABLE (-1 IN DPTCUR)
  ELSE STORE CURRENT DATA IN RAM
       STORE CURRENT DATA IN 1-MIN STACK
ENDIF
IF((ERROR FLAG SET).OR.(DATA MISSING).OR.(NOT ONE
.         MINUTE OF GOOD DATA))
. THEN SET AVERAGE NOT AVAILBLE (-1 IN DP1AVG)
.      SET ASCII BUFFER TO '
. ELSE CALL AVG TO TAKE STACK AVERAGE
.      STORE AVERAGE IN RAM
.      CONVERT TO ASCII DECIMAL
.      STORE IN ASCII BUFFER
.      IF(ERROR FLAG.GT.0)
.      . THEN SET ERROR FLAG TO 0
.      ENDIF
ENDIF
```

RESCHEDULE IN 10 SECONDS
RETURN
END

ERROR PROCESSING:

IF THERE ARE TWO ERRORS OR MORE IN ONE MINUTE, THE ERROR FLAG IS SET, AND THE ERROR COUNT IS INCREMENTED. IF DATA IS NOT AVAILABLE, THE CURRENT DPT (DPTCUR) AND THE 1-MIN AVERAGE (DP1AVG) ARE SET TO -1, AND THE ASCII BUFFER IS SET TO M (MISSING).

DEWPT

Purpose: DEWPT calculates the five-minute dew point average. It is called once each minute.

Variable Names:

```
 DP5AVG - 5-MIN DEW POINT AVERAGE
 DP5ASC - 5-MIN DEW POINT ASCII BUFFER
 DP1AVG - 1-MIN DEW POINT AVERAGE
 DPTMN  - ROUTINE NAME IN SCAN TABLE
 DP5TBL - 5-MIN STACK
 DPTC   - 10-SEC ERROR COUNT
 DPTCNT - 1-MIN ERROR COUNT
 DPTOK  - DPT OFFSET
```

Method:

```
PUSH DOWN 5-MINUTE STACK
IF(10-SEC ERROR COUNT.NE.0)
  THEN INCREMENT 1-MIN ERROR COUNT
ENDIF
CLEAR 10-SEC ERROR COUNT
GET 1 MINUTE AVERAGE
STORE AVERAGE OR -1 (OFFH) IN STACK IF ERROR IS DETECTED
IF(1-MIN AVG MISSING.OR.1ST 4  MINUTES.OR.
  NOT 5 MIN GOOD DATA)
  THEN SET 5-MIN AVG MISSING (-1 IN DP5AVG)
       SET ASCII BUFFER TO M
  ELSE TAKE SUM OF 5-MIN STACK
       DIVIDE TO TAKE  5-MIN AVERAGE
       STORE 5-MIN AVERAGE IN RAM
       SUBTRACT DEWPOINT OFFSET (97)
       CONVERT TO ASCII DECIMAL
       STORE IN ASCII BUFFER
ENDIF
RESCHEDULE FOR NEXT MINUTE
RETURN
END
```

ERROR PROCESSING:

IF THE 5-MIN AVERAGE IS MISSING, DP5AVG IS SET TO -1, AND THE ASCII BUFFER IS SET TO M. IF THE 10-SEC ERROR COUNT IS NOT ZERO, THE 1-MIN ERROR COUNT IS INCREMENTED.

3.12.3 WIND SPEED

The wind speed data is processed by subroutines "WS" and "GUST".

WS

Purpose: WS performs wind speed quality control and one-minute averaging. It is called once each second.

Variable Names:

```
  AD BL  - TABLE OF A/D CHANNEL VOLTAGES
  WSSEC  - ROUTINE NAME IN SCAN TABLE
  WSFLG  - ERROR FLAG
  WSCNT  - 1-SEC ERROR COUNT
  WS1AVG - 1 MIN AVERAGE
  WS1ASC - 1-MIN ASCII BUFFER
  WSCUR  - CURRENT WIND SPEED
  WS1TBL - 1-MINUTE STACK
  VLTMIN - VOLTAGE MINIMUM
  VLTMAX - VOLTAGE MAXIMUM
  WSBIAS - BIAS TO WIND SPEED
```

Method:

```
PUSH 1-MINUTE STACK DOWN
GET VOLTAGE FROM RAM
CONVERT VOLTAGE TO WIND SPEED (DIVIDE BY 8.2)
ADD WIND SPEED BIAS
IF(VOLTAGE LIMITS EXCEEDED.OR.WS.GT.125 KNOTS)
  THEN SET ERROR FLAG
       INCREMENT ERROR COUNT
       SET DATA MISSING(=FFH)
       SET AVERAGE MISSING
  ELSE STORE CURRENT WS
        STORE CURRENT WS IN 1 MIN STACK
       IF(ERROR FLAG.GT.O.AND.5 SEC OF GOOD DATA)
         THEN SET ERROR FLAG=0
       ENDIF
       IF(1ST 59 SEC OR NOT 60 SEC OF GOOD DATA)
         THEN SET AVERAGE MISSING
         ELSE COMPUTE AVERAGE OF 60 GOOD VALUES
            IF WS AVG .LE. 2
              THEN SET WS AVG = 0 (calm conditions)
              ELSE CONTINUE
            ENDIF
         STORE AVERAGE IN RAM
         CONVERT TO ASCII DECIMAL
         STORE ASCII IN BUFFER
       ENDIF
ENDIF
RESCHEDULE FOR NEXT SECOND
RETURN
END
```

ERROR PROCESSING:

WS CHECKS FOR VOLTAGE LIMITS, 0 TO 1024.
WS .GT.125 KNOTS IS ERROR

```
WSCNT- ERROR COUNT INCREMENTED WITH EACH FAILURE
       1 SEC VALUE SET TO OFFH, AVG SET TO OFFH, ASCII AVG='M'
WSFLG-  HE ERROR FLAG IS RESET TO 0 AFTER 5 SECONDS OF GOOD DATA.
```

GUST

Purpose· Gust calculates the 10-minute maximum gust and 1-minute peak wind. It is called once each minute.

Varia le Names:

```
  BINASD - CONVERTS BINARY TO ASCII DECIMAL
  SCHED  - SCHEDULES ROUTINE IN SCAN TABLE
  PUSHDN - PUSHES DOWN STACK WITH 1-BYTE ENTRIES
  AVG    - AVERAGES TABLE WITH 1-BYTE ENTRIES
  MXX    - FINDS MAXIMUM IN BUFFER
  WS1AVG - 1-MIN AVERAGE WIND SPEED
  WS TBL -   -MIN STACK FOR WIND SPEED
  GSTTBL - GUST 10-MIN STACK
  GSTCUR - CURRENT GUST
  GSTASC - GUST ASCII BUFFER
  GSTMN  - ROUTINE NAME IN SCAN TABLE
  PKWASC - PEAK WIND ASCII BUFFER
```

Method:

```
PUSH DOWN 10-MINUTE STACK
GET 1-MIN AVERAGE WIND SPEED FROM RAM
IF(WS AVERAGE MISSING)
  THEN GUST MISSING (-1 IN GSTCUR, BLANKS IN GSTASC)
       PEAK WIND MISSING (BLANKS IN PKWASC)
  ELSE TAKE ONE-MINUTE WS MAXIMUM
       STORE MAX IN 10-MIN TABLE
       CONVERT 1-MIN MAXIMUM TO ASCII DECIMAL
       STORE IN PEAK WIND ASCII BUFFER
       DETERMINE MAX10 IN 10-MIN TABLE
       IF(MAX10.GE.14.AND.MAX10.GE.(1 MIN AVG+5))
         THEN SET GUST = MAX10
              CONVERT TO ASCII DECIMAL
              STORE IN ASCII BUFFER
         ELSE GUST MISSING
       ENDIF
ENDIF
RESCHEDU E FOR NEXT MINUTE
RETURN
END
```

ERROR PROCESSING·

IF GUST IS MISSING. GSTCUR IS SET TO -1 AND
GSTASC IS FILLED WITH BLANKS

3.2.4 WIND DIRECTION

Wind direction data is processed by subroutines "WD" and "WNDDIR".

WD

Purpose: Sample the wind direction sensor's inputs (remote A/D channels 5, 6, and 7) once a second, convert the data to a wind direction reading and average samples over 1 minute to form a 1 minute wind direction.

Variable Names:

```
  ADTBL - RAM ADDRESS OF THE REMOTE A/D DATA BUFFER
  WDSEC - MODULE TIME TABLE ADDRESS OF 'WD' MODULE.
  WD1AVG- RAM ADDRESS OF 1 MINUTE WIND DIRECTION AVERAGE
  WDFAIL- 1 SECOND FAILURE COUNT
  WNDAVG- RUNNING AVERAGE STORAGE
  ATAP,BTAP, CTAP-TEMPORARY STORAGE FOR WIND DIRECTION PHASES.
```

Method:

THREE WIND DIRECTION PHASES ARE SAMPLED EACH SECOND. EACH PHASE IS SCALED BY EXTRACTING THE 8 MSB'S FROM THE 12 BIT SAMPLE, I.E. DIVIDING BY 16. WIND DIRECTION IS THEN CALCULATED BY DETERMINING THE PROPER PHASE TO BE USED BASED ON THE RELATIVE MAGNITUDES OF THE PHASES. THE RESULTANT RUNNING WIND DIRECTION IS SCALED TO 255/360.

```
GET:
A=(CH.5)/16 (TRUNCATED TO 8 BITS)
B=(CH.6)/16 (TRUNCATED  "  "   " )
C=(CH.7)/16 (TRUNCATED  "  "   " )
IF A .GT. HIGH LIMIT (119 DEGREES)
.  THEN IF A .GT. B AND A .GT. C
.        .   THEN IF B+C .LE. A AND B+C .GT. LOWER LIMIT(59
.        .       .                                  DEGS.SCALED, 42)
.        .       .  THEN IF B/2 .GT. 42
.        .       .        .  THEN DIRECTION=B/2-42
.        .       .        .  ELSE DIRECTION=B/2+300 SCALED (212)
.        .       .        ENDIF
.        .       .        GO TO AVG
.        .       .  ELSE INCREMENT FAILURE COUNT
.        .       .  GO TO FAIL
.        .       ENDIF
.        ENDIF
ENDIF
IF B .GT. HIGH LIMIT
.  THEN IF B .GT. C AND B .GT. A
.        .  THEN IF C+A .LE. B AND C+A .GT. LOWER LIMIT
.        .       .  THEN DIRECTION=C/2+60 DEGREES SCALED (42)
.        .       .       GO TO AVG
.        .       .  ELSE GO TO FAIL
.        .       ENDIF
.        ENDIF
ENDIF
```

```
IF C .GT. HIGH LIMIT
.   THEN IF C .GT. B AND C .GT. A
.        .  THEN IF B+A .LE. C AND B+A .GT. 42
.        .       .  THEN DIRECTION=A/2+180 DEGREES SCALED (128)
.        .               GO TO AVG
.        .       .  ELSE GO TO FAIL
.        .       ENDIF
.        ENDIF
ENDIF
IF A=B AND B .GE. EQUAL LIMIT (120 SCALED)
.  THEN IF C .LT. LOWER VALUE (3)
.        .  THEN DIRECTION = C/2+60 DEGREES SCALED (42)
.        .       GO TO AVG
.        .  ELSE GO TO FAIL
.       ENDIF
ENDIF
IF B=C AND B .GE. EQUAL LIMIT
.  THEN IF A .LT. LOWER VALUE (3)
.        .  THEN D RECTION=A/2+180 DEGREES SCALED (128)
.        .       GO TO AVG
.        .  ELSE GO TO FAIL
.       ENDIF
ENDIF
IF A=C AND A .GE. EQUAL LIMIT
.  THEN IF B .LT. LOWER LIMIT (3)
.        .  THEN IF B/2 .GT. 42
.        .       .  THEN DIRECTION=B/2-42
.        .       .  ELSE DIRECTION=B/2+300 DEGREES SCALED (218)
.        .       ENDIF
.        .     GO TO AVG
.        .  ELSE GO TO FAIL
.       ENDIF
ENDIF
FAIL: INCREMENT FAILURE COUNT
RESCHEDULE FOR 1 SECOND
RETURN
AVG: COMPUTE INSTANTANEOUS AVERAGE (I
AVG=INSTANTANEOUS-PREVIOUS AVERAGE
            (MODULO 255. I.E. SHIFT RIGHT 5 BITS; AVG=(I-AVG)/32+AVG)
            (1 MINUTE AVERAGE= AVG/32)
RESCHEDULE FOR 1 SECOND
RETURN
END
```

ERROR PROCESSING:

EACH PHASE IS TESTED AGAINST DESIGNATED LIMITS. THE SUM OF THE TWO SMALLER PHASES MUST BE LESS THAN THE LARGER PHASE. FOR EACH FAILURE DETECTED. A FAILURE COUNT IS INCREMENTED, TO BE USED BY 'WNDDIR' TO DETERMINE IF THE 1 MINUTE AVERAGE IS ACCEPTABLE. THE FAILURE COUNT IS RESET EACH MINUTE

WNDDIR

Purpose: Compute wind direction once per minute, true and magnetic, convert both to 10's of degrees in ASCII for reporting.

Variable Names:

```
  WDFAIL-1 MIN. FAILURE COUNT FOR DIRECTION
  WD1AVG-WIND DIRECTION 1-MINUTE AVERAGE(5 BYTES)
  WS1AVG-WIND SPEED 1-MINUTE AVERAGE (5 BYTES)
  MAGOFF-MAGNETIC NORTH DIRECTION OFFSET
  BINASD-BINARY TO ASCII DECIMAL CONVERSION
  SCHED -SCHEDULE A MODULE FOR EXECUTION BY 'SCAN'
  MOUT  -OUTPUT '     M' TO AN ASCII BUFFER
  WD1ASC-1 MINUTE DIRECTION IN 10'S OF DEGREES ASCII
  WDMN  -1 MINUTE MAGNETIC WIND DIRECTION
  WDMASC-1 MINUTE MAGNETIC DIRECTION IN 10'S OF DEGREES ASCII
  WDCNT -WIND DIRECTION ERROR COUNT
```

Method:

```
IF WD1ASC=0. I.E. ASCII BUFFER EMPTY
A:   THEN SET ASCII BUFFERS='M'
.        CLEAR 1 MINUTE FAILURE COUNT
.        RESCHEDULE FOR 1 MINUTE
.        RETURN
.    ELSE IF FAILURE COUNT .GE. 3
.         .  THEN INCREMENT ERROR COUNT (WDCNT)
.         .     GO TO A.
.         ENDIF
ENDIF
IF SPEED AVERAGE=0
   THEN PUT 0 IN TRUE ASCII WIND DIRECTION BUFFER (WD1ASC)
   ELSE CALL CONVERT (CONVERT DIRECTION TO 10'S OF DEGREES)
     CONVERT TO ASCII (BINASD)
     STORE IN TRUE ASCII BUFFER (WD1ASC)
ENDIF
IF TRUE DIRECTION=0
   THEN PUT 0 IN MAGNETIC ASCII BUFFER
   ELSE MAGNETIC DIR=TRUE AVG.+MAG. OFFSET)
       CALL CONVERT(CONVERT TO 10's OF DEGREES)
       CONVERT TO ASCII
       STORE IN MAGNETIC ASCII BUFFER (WDMASC)
ENDIF
CLEAR 1 MINUTE FAILURE COUNT
RESCHEDULE FOR 1 MINUTE
RETURN
CONVERT:
 IF DIRECTION .LE. 7 DEGREES (SCALED)
    THEN SET DIRECTION=36 (360 degrees)
    ELSE CONVERT DIRECTION FROM 255 TO 360 SCALING
 DIRECTION IN 10'S OF DEGREES= DIRECTION/7
ENDIF
RETURN
END
```

ERROR PROCESSING:
FOR EACH 1 MINUTE FAILURE COUNT .GE. 3 THE WIND DIRECTION

ERROR COUNT IS INCREMENTED AND WIND DIRECTION OUTPUT IS MISSING 'M'.

ASSUMPTIONS: CURRENT WIND SPEED HAS BEEN CALCULATED PRIOR TO THE EXECUTION OF THIS MODULE.

3.12.5 PRECIPITATION

Precipitation data is processed by subroutine "PRECIP".

PRECIP

Purpose: Identification and tracking of precipitation, outputs a remark indicating the beginning and ending times of precipitation. It is executed once a minute.

```
Variable Names:
  TIMASC- CURRENT TIME (ASCII) IN RAM
  SCHED - SCHEDULE A ROUTINE FOR EXECUTION BY 'SCAN'
  STANUM- STORE A CONSTANT X TIMES IN RAM
  PRECMN- MODULE ENTRY POINT IN 'SCAN' TIME TABLE
  RASC  - PRECIPITATION REMARK ASCII BUFFER ADDRESS
  TIMASC- CURRENT TIME ASCII BUFFER ADDRESS
  MINS  - CURRENT MINUTE
  ZRASC - FREEZING RAIN REMARK ASCII BUFFER ADDRESS
  EVENT - EVENT SENSOR WORD IN RAM
          Bit 7 - NOT USED
              6 - FREEZING RAIN (not used in this version)
              5 - THUNDERSTORM
              4 - RAIN
              3 - NOT USED
              2 -  "   "
              1 -  "   "
              0 - DAY/NIGHT

  PCPFLG- PRECIPITATION FLAG WORD
          BIT 7 - MARKS CHANGING OF HOUR
              6 - RAIN IN PROGRESS INDICATOR
              5 - NOT USED (SET TO 1)
              4 - RAIN. FIRST INDICATOR
              3 - 15 MINUTE COUNTER
              2   "     "      "
              1   "     "      "
              0   "     "      "
  TIMSTR- STORAGE FOR ASCII BEGINNING AND ENDING TIMES
```

Method:

```
IF FIRST EXECUTION
   THEN CLEAR ASCII RAIN AND FREEZING RAIN BUFFERS
ENDIF
GET CURRENT EVENT SENSOR DATA
IF EVENT SENSOR WORD BIT 4 (RAIN) = 0
    THEN CLEAR BIT 4 OF PRECIP FLAG WORD
    ELSE RESET BIT 4 OF EVENT SENSOR WORD
         SET BIT 4 OF PRECIP FLAG WORD
ENDIF
```

```
IF PRECIP FLAG WORD .GE. 80H AND .LE.BOH  (Chg in Hr. & rain not
                                           reported in previous 15 minutes ?)
   THEN CLEAR ASCII BUFFER
   ELSE IF PRECIP FLAG WORD .GE. EOH (Chg in Hr & rain prev. reported?)
           THEN CLEAR BXXEXX IN ASCII BUFFER
        ENDIF
ENDIF
CLEAR HOUR BIT (BIT 7) IN FLAG WORD
IF PRECIP FLAG=10H   (Rain 1st Ind. and mins. count = 0?)
   THEN SET BITS 6,5.4 OF FLAG WORD(Set rain in prog.-bit 5,& 1st Ind.)
        SET PBXX IN ASCII BUFFER, RAIN BEGINNING
   ELSE CONTINUE
ENDIF
IF PRECIP FLAG WORD .GE. 60H AND .LE. 6FH(rain in prog.& min.=0 to 15?)
.   THEN INCREMENT PRECIP FLAG WORD (15 MINUTE COUNTER)
.        IF PRECIP FLAG WORD = 61H (Rain prev. Ind. but not at present
.        .                          and minute count = 1?)
.        .  THEN SAVE CURRENT TIME AS END TIME TO BE OUTPUT IN 14 MINS.
.        ENDIF
.   ELSE CONTINUE
ENDIF
IF PRECIP FLAG=6FH (Rain prev. Ind. but not at present & count = 15?)
   THEN CLEAR PRECIP FLAG
        OUTPUT PEXX END TIME (RAIN ENDED 14 MINS. AGO)
   ELSE CONTINUE
ENDIF
IF PRECIP FLAG .GE. 70H (Rain prev. Ind. & rain 1st Ind. set?)
   THEN SET PRECIP FLAG=60H (Rain still in progress,reset 15 min count)
ENDIF
SAVE CURRENT TIME
IF CURRENT MINUTE=00
   THEN SET PRECIP FLAG BIT 7=1 (Set hour change indicator bit)
ENDIF
SAVE PRECIP FLAG WORD
RESCHEDULE FOR 1 MINUTE
RETURN
END
```

NO ERROR PROCESSING

3.12.6 THUNDERSTORM

Thunderstorm data is processed by subroutines "TUNDER" and "LITEN".

TUNDER

Purpose: To read and reset the events port and store the results in RAM. To check for lightning in the past second and set a flag if present.

```
Variable Names:
  SCHED  - MODULE SCHEDULER FOR EXECUTION BY 'SCAN'
  TUN    - ENTRY IN 'SCAN' TIME TABLE FOR 'TUNDER'
  TUNFLG - THUNDERSTORM FLAG WORD IN RAM  (accessed also by subroutine
                     'LITEN')
             BIT 7 - Marks beginning of new hour  (80H)
             BIT 6 - Storm reported in progress  (40H)
             BIT 5 - 2nd stroke, storm beginning  (20H)
             BIT 4 - Lightning strike, set by subroutine TUNDER  (10H)
             BIT 3 - MSB of 15 minute counter
             BIT 2 -        "   "       "
             BIT 1 -        "   "       "
             BIT 0 - LSB of "   "       "

  EVENT - EVENT SENSOR WORD IN RAM
          Bit 7 - NOT USED
              6 - FREEZING RAIN (not used in this version)
              5 - THUNDERSTORM
              4 - RAIN
              3 - NOT USED
              2 -  "   "
              1 -  "   "
              0 - DAY/NIGHT
```

Method:

```
READ EVENT SENSOR PORT (8-BITS)
COMPLEMENT EVENT DATA (Invert all 8 data bits)
LOGICALLY OR DATA WITH PREVIOUS EVENT DATA WORD
STORE IN 'EVENT' DATA WORD IN RAM
RESET EVENT ELECTRONICS
IF EVENT DATA WORD BIT 5=1 (Strike detected this second)
.  THEN IF TUNFLG FLAG WORD BIT 4 .NE. 1
.        .  THEN SET TUNFLG BIT 4=1 (FIRST HIT THIS MINUTE)
.        .  ELSE SET TUNFLG BIT 5=1 (2ND HIT THIS MINUTE)
.       ENDIF
   ELSE CONTINUE
ENDIF
RESCHEDULE FOR NEXT SECOND
RETURN
END
```

LITEN

Purpose: To determine the beginning and ending times of thunderstorms according to the prescribed algorithm. Output a "T" for thunderstorm, "BXX" for beginning time and "EXX" for ending time. The program is executed once each minute.

Var'able Names:

```
  BINASD - BINARY TO ASCII
  SCHED  - SCHEDULE MODULE FOR EXECUTION BY SCAN
  TRMASC - THUNDERSTORM REMARK ASCII BUFFER
  TIMASC - CURRENT TIME (ASCII) BUFFER ADDRESS IN RAM (HHMM)
  TIMSTR - BEGINNING AND ENDING TIME STORAGE
  LIT    - MODULE ENTRY POINT IN 'SCAN' TIME TABLE FOR LITEN
  TUNFLG - THUNDERSTORM FLAG WORD IN RAM  (changed also by subroutine
              'TUNDER')
              BIT 7 - Marks beginning of new hour  (80H)
              BIT 6 - Storm reported in progress  (40H)
              BIT 5 - 2nd stroke, storm beginning  (20H)
              BIT 4 - Lightning strike, set by subroutine TUNDER  (10H)
              BIT 3 - MSB of 15 minute counter
              BIT 2 -        "   "       "
              BIT 1 -        "   "       "
              BIT 0 - LSB of "   "       "
```

Method:

```
GET TUNFLG FROM RAM
IF TUNFLG = 0
   THEN RETURN
ENDIF
IF TUNFLG .GE. 80H AND .LE. BOH  (Hr. chg & no T'storm reported in
                                   prev.15 mins.?)
   THEN CLEAR TRMASC          (Clear all T'storm remarks)
   ELSE IF TUNFLG .GE. EOH        (Hr. chg & T'storm prev.reported?)
          THEN CLEAR BXXEXX AND SET "T" ONLY IN TRMASC
        ENDIF
ENDIF
IF TUNGLG .GE. 80H
   THEN SET TUNFLG = TUNFLG - 80H     (Clr. Hr. chg bit)
ENDIF
IF TUNFLG = 10H                 (1st strike ind. this min.?)
   THEN SET TUNFLG = 20H      (Set bit 5, possible storm begin time)
   GO TO "DONE"
   ELSE CONTINUE
ENDIF
IF TUNFLG .GE. 20H and .LE. 2EH   (.LT. 15 mins. since 1st strike?)
   THEN INCREMENT TUNFLG          (Yes, incr. 15 min. counter)
        IF TUNFLG = 2FH          (15 mins. since 1st & only strike?)
           THEN SET TUNFLG = 0 (Yes, clr. flag and don't report T'storm)
        ENDIF
        GO TO "DONE"
   ELSE CONTINUE
ENDIF
```

```
IF TUNFLG .GE. 30H AND .LE. 3EH      (Two strikes within 14 minutes?)
   THEN SET TUNFLG = 60H, MOVE TBXX TO TRMASC    (Yes,report begin time)
   GO TO "DONE"
   ELSE CONTINUE
ENDIF
IF TUNFLG .GE. 60H AND .LE. 6EH   (.LT. 15 min.since T'storm reported?)
.  THEN INCREMENT TUNFLG          (Yes, incr. 15 min. counter)
.    IF TUNFLG .EQ. 61H (1st min.since T'storm reported & last strike?)
.    .  THEN SAVE TIME AS POSSIBLE ENDTIME
.    ENDIF
.    IF TUNFLG = 6FH  (T'storm reported & 15 min. since last strike?)
.    .  THEN SET TUNFLG = 0          (Yes, clr flag)
.    .     MOVE EXX TO TRMASC         (Set T'storm end time)
.    .     GO TO "DONE"
.    .  ELSE GO TO "DONE1"
.    ENDIF
.  ELSE CONTINUE
ENDIF
IF TUNFLG .GE. 70H     (Strike in .LT. 15 min. since T'storm reported?)
   THEN SET TUNFLG = 60H     (Yes, reset 15 min. counter for end time)
ENDIF
DONE:
GET MINUTES FROM RAM
SAVE MINUTES                (Save current time in TIMSTR)
DONE1:
IF MINUTES = 0                              (Hr. chg.?)
   THEN TUNFLG = TUNFLG + 80H               (Yes, set bit 7)
ENDIF
SAVE TUNFLG
RESCHEDULE FOR NEXT MINUTE
RETURN
END

NO ERROR PROCESSING
```

3.12.7 PRESSURE & ALTIMETER SETTING

Pressure and altimeter setting data are processed by subroutines "CALINT", "PRSAQ1", PRSAQ2", and "PRSPC1".

CALINT

PURPOSE:	THIS MODULE SAMPLES A REFERENCE VOLTAGE THAT PROVIDES 3.33 VOLTS TO ONE CHANNEL OF THE INTERNAL A/D CONVERTER. IF IT DETECTS AN OUT OF RANGE VOLTAGE IT SETS AN ERROR FLAG AND DISPLAYS AN ERROR MESSAGE ON THE CONSOLE. THE ERROR FLAG IS USED BY THE PRESSURE ACQUISITION MODULES TO VALIDATE THE PRESSURE READINGS.
EXECUTION:	SCHEDULED TO EXECUTE JUST PRIOR TO THE PRESSURE ACQUISITION MODULES EACH 10 SEC. IT IS CALLED BY SCAN AND RESCHEDULES ITSELF FOR THE NEXT 10 SEC TIME.
DESCRIPTION:	THIS MODULE CHECKS A REFERENCE VOLTAGE DERIVED FROM THE COMPUTER'S 5 VOLT POWER SUPPLY TO VERIFY THAT THE COMPUTER VOLTAGE AS WELL AS THE INTERNAL A/D CONVERSION CARD ARE OPERATING CORRECTLY AND ARE WITHIN TOLERANCE. IF IT IS NOT, THEN AN ERROR FLAG(CALFLG) IS SET, AND AN ERROR MESSAGE IS OUTPUT TO THE CONSOLE. IT TAKES 30 CONSECUTIVE GOOD READINGS TO CLEAR THE ERROR FLAG(5 MINUTES).

Variable Names:

- CALLMT - THE LIMIT THAT THE VOLTAGE MAY VARY FROM NORMAL. IT IS PRESENTLY SET TO 8 (9.77 MILLIVOLTS).
- CALVOL - THE VALUE EXPECTED FROM THE SAMPLED VOLTAGE. PRESENTLY SET TO 3.332 VOLTS.
- CALOG - THE CHANNEL AND GAIN THE SAMPLED REFERENCE IS WIRED TO THE INT. A/D. PRESENTLY CHANNEL 13.
- CALFLG - FLAG INDICATES WHEN -1 THAT PRESSURE VOLTAGE SUPPLY BAD
- CALERR - COUNTER THAT REQUIRES 30 GOOD PRESSURE VOLTAGE SUPPLY READINGS BEFORE THE ERROR FLAG IS CLEARED.

INITIALIZATION REQUIREMENTS:	ERROR COUNTER (CALERR) AND ERROR FLAG (CALFLG) SET TO ZERO
INPUTS:	NONE
OUTPUTS:	ERROR FLAG SET AND MESSAGE TO CONSOLE DISPLAY IF BAD VOLTAGE.

METHOD:

```
GET CALIBRATION VOLTAGE
IF(VOLTAGE EXCEEDS LIMITS)
.  THEN SET ERROR COUNT TO 30 (CALERR)
.      OUTPUT ERROR MESSAGE TO DISPLAY
.      SET ERROR FLAG = -1 (CALFLG)
.  ELSE IF ERROR COUNTER NOT ZERO
.          .  THEN DECREMENT ERROR COUNTER
.          .     IF ERROR COUNTER EQUAL ZERO
.          .     .  THEN RESET ERROR FLAG = 0 (CALFLG)
.          .     ENDIF
.          ENDIF
ENDIF
RESCHEDULE IN TEN SECONDS
RETURN TO SCAN
END
```

ASSUMPTIONS:
1. MUST HAVE REFERENCE VOLTAGE WIRED TO INTERNAL A/D CH 13
2. MUST HAVE SENSOR INTERFACE BOARD INSTALLED

PRSAQ1

PURPOSE:
PRSAQ1 ACQUIRES PRESSURE DATA FROM THE FIRST SENSOR THROUGH THE LOCAL A/D CONVERTER AND ALSO READS THE OFFSET VOLTAGE FOR THE FIRST SENSOR ON A SEPARATE CHANNEL. THE MODULE THEN ADDS THE OFFSET TO THE PRESSURE AND SAVES THE RESULT IN A ONE MINUTE (6 PER MINUTE) STACK.

DESCRIPTION:
THE MODULE IS SCHEDULED TO EXECUTE ONCE EACH 10 SECONDS. PRESSURE DATA FROM SENSOR #1 IS READ FROM THE INTERNAL A/D CONVERTER AND SAVED IN A TEMPORARY LOCATION. AN OFFSET VOLTAGE IS READ FROM ANOTHER CHANNEL OF THE A/D CONVERTER AND ADDED TO THE PRESSURE DATA. THIS OFFSET VOLTAGE IS ADJUSTABLE AND IS USED TO CALIBRATE THE SENSOR READING. THE PRESSURE DATA WITH OFFSET ADDED IS THEN SAVED IN A DATA STACK CONTAINING THE LAST SIX READINGS. THE DATA IS THEN COMPARED AGAINST A HIGH AND LOW LIMIT TO BE SURE IT IS VALID. IF IT EXCEEDS THE LIMITS THE DATA IS REPLACED BY A -1 (OFFH) IN THE STACK. FINALLY THE DATA IS COMPARED TO THE LAST READING TO SEE THAT THE DIFFERENCE DOESN'T EXCEED A SET AMOUNT (PRESENTLY PRSDEV = 20 = 0.072 INCHES HG.). IF IT DOES EXCEED THIS VALUE THEN THE DATA IS REPLACED BY -1. THE MODULE THEN RESCHEDULES FOR THE NEXT 10 SECOND PERIOD AND RETURNS TO SCAN.

Variable Names:
PRS1DA - SENSOR #1 RAW PRESSURE DATA VALUE
PRS1OF - PRESSURE SENSOR #1 DATA STACK (6 WORDS)
PR1ERF - ERROR FLAG INITIALLY SET TO 0
PR1ERC - PRESSURE SENSOR ERROR COUNTER INITIALLY SET TO 0
PRS1CH - EQUALS 03 (A/D channel #), PRESSURE SENSOR #1
P1OFCH - EQUALS 15 (A/D channel #), SENSOR #1 OFFSET
HILMT - EQUALS 3768, HIGH LIMIT SENSOR VOLTAGE (4.600 V. MAX.)
LOLMT - EQUALS 0 , LOW LIMIT SENSOR VOLTAGE (0.000 V.)
PRSDEV - EQUALS 20, ALLOWED PRESSURE DEVIATION BETWEEN 10 SECOND READINGS.

Method:

```
MOVE 1 MINUTE STACK DOWN
GET PRESSURE AND OFFSET AND ADD
SAVE BOTH DATA AND OFFSET DATA VALUES
IF DATA EXCEEDS HIGH LIMIT
   THEN SAVE -1 IN DATA LOCATION
     SET ERROR FLAG AND INCREMENT ERROR COUNT
   ELSE CONTINUE
ENDIF
IF DATA IS BELOW LOWER LIMIT
   THEN SAVE -1 IN DATA STACK
     SET ERROR FLAG AND INCREMENT ERROR COUNT
   ELSE CONTINUE
ENDIF
IF DIFFERENCE BETWEEN LAST TWO READINGS EXCEEDS PRSDEV
   THEN SAVE -1 IN DATA STACK
     SET ERROR FLAG AND INCREMENT ERROR COUNT
   ELSE SAVE DATA
ENDIF
RESCHEDULE IN 10 SECONDS
RETURN TO SCAN
END
```

PRSAQ2

PURPOSE:
PRSAQ2 ACQUIRES PRESSURE DATA FROM THE SECOND SENSOR THROUGH THE LOCAL A/D CONVERTER AND ALSO READS THE OFFSET VOLTAGE FOR THE SECOND SENSOR ON A SEPARATE CHANNEL. THE MODULE THEN ADDS THE OFFSET TO THE PRESSURE AND SAVES THE RESULT IN A ONE MINUTE (6 PER MINUTE) STACK.

DESCRIPTION:
THE MODULE IS SCHEDULED TO EXECUTE ONCE EACH 10 SECONDS. PRESSURE DATA FROM SENSOR #2 IS READ FROM THE INTERNAL A/D CONVERTER AND SAVED IN A TEMPORARY LOCATION. AN OFFSET VOLTAGE (SEPARATE FROM SENSOR #1's OFFSET ADJUSTMENT) IS READ FROM ANOTHER CHANNEL OF THE A/D CONVERTER AND ADDED TO THE PRESSURE DATA. THIS OFFSET VOLTAGE IS ADJUSTABLE AND IS USED TO CALIBRATE THE SENSOR READING. THE PRESSURE DATA WITH OFFSET ADDED IS THEN SAVED IN A DATA STACK CONTAINING THE LAST SIX READINGS. THE DATA IS THEN COMPARED AGAINST A HIGH AND LOW LIMIT TO BE SURE IT IS VALID. IF IT EXCEEDS THE LIMITS, THE DATA IS REPLACED BY A -1 (OFFH) IN THE STACK. FINALLY THE DATA IS COMPARED TO THE LAST READING TO SEE THAT THE DIFFERENCE DOESN'T EXCEED A SET AMOUNT (PRESENTLY PRSDEV = 20 = 0.072 INCHES HG.). IF IT DOES EXCEED THIS VALUE THEN THE DATA IS REPLACED BY -1. THE MODULE THEN RESCHEDULES FOR THE NEXT 10 SECOND PERIOD AND RETURNS TO SCAN.

Variable Names:

```
PRS2DA - SENSOR #2 RAW PRESSURE DATA VALUE
PRS2OF - PRESSURE SENSOR #2 DATA STACK (6 WORDS)
PR2ERF - ERROR FLAG INITIALLY SET TO 0
PR2ERC - PRESSURE SENSOR ERROR COUNTER INITIALLY SET TO 0
PRS2CH - EQUALS 04 (A/D channel #) , PRESSURE SENSOR #2
P2OFCH - EQUALS 14 (A/D channel #) , SENSOR #2 OFFSET
HILMT  - EQUALS 3768 , HIGH LIMIT SENSOR VOLTAGE (3768=4.600 V.MAX.)
LOLMT  - EQUALS 0 , LOW LIMIT SENSOR VOLTAGE
```

PRSDEV - EQUALS 20, ALLOWED PRESSURE DEVIATION
BETWEEN 10 SECOND READINGS.

```
Method:
MOVE 1 MINUTE STACK DOWN
GET PRESSURE AND OFFSET AND ADD
SAVE BOTH DATA AND OFFSET DATA VALUES
IF DATA EXCEEDS HIGH LIMIT
   THEN SAVE -1 IN DATA LOCATION
     SET ERROR FLAG AND INCREMENT ERROR COUNT
   ELSE CONTINUE
ENDIF
IF DATA IS BELOW LOWER LIMIT
   THEN SAVE -1 IN DATA STACK
     SET ERROR FLAG AND INCREMENT ERROR COUNT
   ELSE CONTINUE
ENDIF
IF DIFFERENCE BETWEEN LAST TWO READINGS EXCEEDS PRSDEV
   THEN SAVE -1 IN DATA STACK
     SET ERROR FLAG AND INCREMENT ERROR COUNT
   ELSE SAVE DATA
ENDIF
RESCHEDULE IN 10 SECONDS
RETURN TO SCAN
END
```

PRSPC1

PURPOSE: THIS MODULE TAKES RAW DATA FROM EACH OF TWO PRESSURE DATA STACKS, AVERAGES, AND CALCULATES STATION PRESSURE FOR EACH. IT ALSO DETERMINES THE ALTIMETER SETTING FROM THE LOWER OF THE TWO PRESSURES. THE MODULE IS EXECUTED ONCE EACH MINUTE.

DESCRIPTION:

THE MODULE GETS THE SIX 10 SEC READINGS FROM THE ONE MINUTE DATA STACK, AVERAGES IT AND CALCULATES STATION PRESSURE USING THE FORMULA-
S.P.=RAW DATA X 0.0036 + 17.718 (.0036 IS FACTOR TO CONVERT RAW DATA TO INCHES HG. & 17.718 IS THE SENSOR OFFSET). IF ANY OF THE SIX READINGS ARE -1 THEN THE ERROR FLAG FOR THAT SENSOR IS SET TO -1 AND NO PRESSURE CALCULATION IS PERFORMED. OTHERWISE THE ERROR FLAG IS CLEARED.

THE RESULT IS SAVED AND ALSO CONVERTED TO ASCII FOR DISPLAY. THE SAME ROUTINE IS USED TO DERIVE THE PRESSURE FOR SENSOR #2. NEXT, THE PRESSURES ARE COMPARED TO -1. IF BOTH ARE -1 THEN NO PRESSURE IS AVAILABLE AND AN 'M' IS OUTPUT. IF ONE IS -1, THEN THE OTHER PRESSURE IS USED TO CALCULATE ALTIMETER SETTING AND A PREFIX 'E' IS PROVIDED. IF BOTH ARE OK, THE LOWER OF THE TWO IS USED TO FIND ALTIMETER SETTING.
ALTIMETER SETTING IS CALCULATED USING THE FORMULA--
A.S. = (S.P. - P1CONT) X A2CONT + STATPR
WHERE A.S. = ALTIMETER SETTING
      P1CONT = P1 VALUE FROM STATION HEIGHT ABOVE SEA LEVEL TABLE.(P1 DULLES CONSTANT = 29573)
      A2CONT = A2 VALUE FROM STATION HEIGHT ABOVE SEA LEVEL TABLE.(A2 DULLES CONSTANT,1/2 VALUE, = 4953)

```
       STATPR = STANDARD PRESSURE AT SEA LEVEL (29.921+.005)
                  .005 IS ADDED FOR ROUNDING

FINALLY THE TWO STATION PRESSURE VALUES DERIVED ABOVE
ARE CHECKED FOR A DIFFERENCE GREATER THAN .04 INCH HG.
IF GREATER, THEN THE ALTIMETER SETTING IS REPLACED WITH
AN 'M'.

Variable Names:
PRSSGN - TEMPORARY LOCATION TO SAVE THE SIGN OF THE
         SUBTRACTION IN THE ALTIMETER EQUATION.
PRSERR - SET TO -1 IF ALTIMETER IS 'M'
         SET TO 1 IF ABS(#1-#2) .GT. 0.04
         SET TO 0 IF PRESSURE OK
PR1ERF - USED TO VERIFY RAW DATA FROM SENSOR #1 OK
PR2ERF - USED TO VERIFY RAW DATA FROM SENSOR #2 OK

INPUTS: RAW PRESSURE DATA FROM 2 SENSORS
OUTPUTS: 1.  STATION PRESSURE IN INCHES HG FOR BOTH SENSORS
         2.  ALTIMETER SETTING IN ASCII
         3.  ASCII STATION PRESSURE FOR BOTH SENSORS

METHOD:

GET 1 MINUTE AVERAGE FOR PRESSURE #1
IF EACH PRESSURE VALUE OK (NOT -1)
        THEN CONTINUE
        ELSE SET PR1ERF = -1
ENDIF
CALCULATE STATION PRESSURE #1
CONVERT TO ASCII
GET 1 MINUTE AVERAGE FOR PRESSURE #2
IF EACH PRESSURE VALUE OK (NOT -1)
        THEN CONTINUE
        ELSE SET PR2ERF= -1
ENDIF
CALCULATE STATION PRESSURE #2
CONVERT TO ASCII
FIND GOOD PRESSURE FOR ALTIMETER CALCULATION
IF BOTH BAD
    THEN OUTPUT 'M'
ENDIF
IF ONLY ONE PRESSURE OK
    THEN USE IT FOR ALTIMETER CALCULATIONS
         INSERT PREFIX "E" FOR ESTIMATED
    ELSE CONTINUE
ENDIF
IF BOTH PRESSURES GOOD
    THEN DETERMINE LOWER VALUE AND USE IT FOR ALTIMETER CALC.
ENDIF
CALCULATE ALTIMETER SETTING
CONVERT TO ASCII
CHECK IF THE ABSOLUTE VALUE OF THE RESULT OF SUBTRACTING
      THE RAW PRESSURES IS GREATER THAN 0.04 INCHES HG.
```

```
IF GREATER THAN 0.04
        THEN OUTPUT 'M' (Missing)
        ELSE CONTINUE
ENDIF
RESCHEDULE MODULE FOR NEXT MINUTE
RETURN (TO SCAN)
```

4. FIELD EVALUATION AT DULLES AIRPORT

The ALWOS system was installed at the Dulles International Airport for evaluation. Output from ALWOS was collected and compared with official weather observations taken by personnel from the collocated National Weather Service (NWS) Office (WSO). Data collection and analysis were performed by members of the NWS Test and Evaluation Division (T&ED), whose offices are located adjacent to Dulles Airport. Maintenance of the system and sensors was provided by the NWS Integrated Systems Laboratory(ISL). The field evaluation lasted for roughly six months, 12 March through 15 September 1981, though data continues to be collected and the system monitored. The ALWOS was not used operationally during the field evaluation. Appendix C contains the evaluation plan.

4.1 System Configuration

Figure 2-1 showed the ALWOS system in block diagram form as configured for the Dulles operation. The various components of the system have been discussed in detail in earlier sections of this report. However, a brief overview of the system concept and operation as related to the field evaluation is important.

4.1.1 Sensors

Most of the sensors are centrally located on the airport, close to the airport's Rotating Beam Ceilometer (RBC) (cloud measurement system) and a transmissometer (visibility measurement system). The sensors included those for wind speed/direction, temperature/dew point, thunderstorm, visibility, and clouds. All sensors were installed according to established procedures for each instrument. Except for the wind sensor which is located at 20 feet above ground level, the remaining sensors are at heights of 10 feet or lower.

The pressure transducers, precipitation, and day/night sensors are located at the NWS office, about .8 mile from the main group of ALWOS sensors. The precipitation Yes/No sensor was eventually moved to center field due to the presence of a nearby large air conditioning unit which adversely affected sensor output (further discussion of this problem is included in a later section of the report). At Dulles Airport the NWS observation point and sensor installations are situated on a building roof, some 40 to 45 feet above ground. Height of the observer is an important factor in the evaluation of ALWOS visibility observations. Later discussion will address this aspect.

4.1.2 Electronics

The CRT display, TI 745 printer, and processors, etc., are located inside the NWS office. Access to the CRT display was restricted to only those personnel involved with the ALWOS evaluation. This excluded the NWS observers from viewing the minute-by-minute updates of the ALWOS output message. Messages on the 745 printer were output well after the times when they could have biased any of the scheduled NWS observations.

The CRT display and voice output in the Dulles tower enabled controllers and other FAA personnel to keep abreast of system

performance. Additional monitoring was performed at the ISL offices in Silver Spring, Maryland, and at the FAA in Washington, D.C. from their remote telephone data drops.

4.2 Data Collection

Hourly and Special surface observations taken at the Dulles WSO served as standards for comparison with the ALWOS outputs. In addition, personnel from T&ED would take supplemental observations when appropriate to further establish system performance. The voice output and CRT display in the Dulles tower allowed for comments on system operation.

4.2.1 ALWOS and WSO Observations

A physical science technician or a meteorologist from T&ED would travel to the Dulles WSO at least three times a week to collect data and check and observe system operation. During each visit, the printout of ALWOS observations was collected from the printer along with copies of the Dulles surface observations, which were made by WSO personnel. Normally these visits to the WSO were scheduled for Monday, Wednesday, and Friday of each week, but if significant weather occurrences developed additional visits were made to observe the response of the ALWOS system. At times, meteorological conditions would warrant T&ED personnel remaining at the WSO for the greater portion of a day.

The T&ED observer would check system operation in several ways:

a. Observe the minute-by-minute updates of the output messages on the CRT for any irregularities.

b. Look for any unusual periods of missing data in the current and previous observations

c. Call up the accounting mode display of errors on the CRT and log the resultant error numbers.

d. Log the last occurrence of system power-up time.

Any problems noted were referred to ISL for discussion and appropriate corrective measures.

4.2.2 ALWOS Output Format

Output messages from ALWOS are printed out every 20 minutes. The sample message below illustrates their format (Section 2.4 briefly touches upon message format):

```
IAD   ALWOS   06/22   2000   270VC   2 1/2   PB27E44
(1)    (2)     (3)     (4)    (5)     (6)      (7)

72/70/2809/967
(8)(9) (10) (11)
```

Note: The numbers in parentheses below the message are used only for identification of message parameters for this report. They are not output in actual operation.

(1) STATION IDENTIFICATION: (Dulles International Airport, VA) Identifies report using FAA identifier.

(2) AUTOMATIC STATION IDENTIFIER

(3) DATE OF REPORT: (June 22) Month/day is reported.

(4) TIME OF REPORT: GMT

(5) CLOUD HEIGHT AND SKY CONDITION: (2700 ft. overcast) Figures are height in 100's of feet above ground. Symbol after height is amount of sky cover.

(6) VISIBILITY: (2 1/2 statute miles)

(7) PRECIPITATION AND/OR THUNDERSTORM OBSERVATIONS: (Precipitation began at 1927 GMT and ended at 1944 GMT). Figures refer to minutes after the hour. P indicates precipitation. T would indicate thunderstorm.

(8) TEMPERATURE: (72 degrees F)

(9) DEW POINT: (70 degrees F)

(10) WIND DIRECTION AND SPEED: (280 degrees at 9 knots) Direction is first two digits reported in tens of degrees. The last digits are speed reported in actual figures.

(11) ALTIMETER SETTING: (29.67 inches) The tens digit and decimal are omitted. A 2 is prefixed whenever the observation begins with an 8 or 9, otherwise a 3 is prefixed; e.g., 017 = 30.17.

Other possible message products are:

a. Cloud Height and Sky Conditions - Partial and total obscurations are reported as -X and WX, respectively. Up to 3 cloud layers are reportable. The maximum reportable cloud height is 3000 feet. If there are no clouds indicated at or below 3000 feet CLR BLO 30 is output.

b. Visibility - Whenever visibility is determined to be variable at the time of observation, it is reported at the end of the ALWOS message in the following format:

x V y

x = lower limit of variability (in miles)
y = upper limit of variability (in miles)

For example, 2 V 3 indicates that the visibility is varying between 2 and 3 miles. The range of visibilities reported in the ALWOS message runs from 0 to 7 miles, with visibilities 8 miles or more reported as 8+.

c. Precipitation and Thunderstorm - P (precipitation) or T (thunderstorm) is output when the event is determined to be occurring at the time of observation.

d. Missing Data - Missing data are indicated with M's in the output message.

4.2.3 Dulles WSO Data Format

The NWS observers at Dulles record their daily surface observations on Form MF1-10, Surface Weather Observations, Parts A and B. Figures 4-1

U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE

SURFACE WEATHER OBSERVATIONS

STATION: Washington, D.C. (WSO, Dulles Int'l Arpt.)

DATE: SEP 01 1981

TO CONVERT LST TO GMT ADD 5 hrs SUBTRACT ___ hrs

Type	Time (LST)	Sky and Ceiling	Visibility (surface)	Visibility (tower)	Weather and Obstructions to Vision	Sea Level Press.	Temp.	Dew Pt.	Wind Direction	Wind Speed	Wind Gusts	Altimeter Setting	Remarks and Supplemental Coded Data	Observer's Initials
SA	0053	28SCT E70BKN 130OVC	5		H	163	71	68	14	04		002	80300 157/ 82	HOC MAC
SM	0100	72403 81404 58058 16322 4557/ 20803 63047 70060											20091 48268①	HOC MAC
SA	0153	M30BKN 70OVC	5		H	160	71	68	00	00		001		MAC
SA	0253	12SCT M30OVC	5		H	158	71	69	13	03		001		MAC
RS	0354	9SCT M26OVC	4		H	158	70	68	00	00		001	605 15//	MAC
SP	0445	26SCT M120BKN	4		H				16	04		000	(FIBI)	MAC
SA	0454	26SCT E120BKN	4		H	156	69	67	16	03		000		MAC
SP	0532	M8BKN 26OVC	3		FH				00	00		002		MAC
SA	0553	M8BKN 40OVC	3		FH	162	70	68	00	00		002	BKN V SCT	MAC
SP	0605	8SCT M38BKN 70OVC	4		FH				00	00		002		MAC
SA	0653	8SCT 38SCT E70OVC	5		H	167	70	68	00	00		003	308 157/ 69 RADAT 53135	MAC
SM	0700	72403 80000 58052 16721 4537/ 20306 63051 48268①												MAC
RS	0753	M6 BKN 35 OVC	5		H	159	73	69	16	06		001		[illegible]
SP	0831	M10 BKN 35 OVC	5		H				15	07		001		[illegible]
SA	0853	M12 BKN 35 OVC	5		H	159	75	68	17	04		001		[illegible]
SP	0942	16 SCT 35 SCT E70 BKN	5		H				15	06		001	(FIBI)	[illegible]
SA	0953	16 SCT 35 SCT E70 BKN	5		H	163	77	68	14	06		002	503 1830	[illegible]
SA	1053	E30 BKN 55 BKN	6		H	163	[illegible]	69	18	[illegible]		[illegible]		[illegible]
RS	1153	M25 BKN	6		H	159	82	70	18	05		001		[illegible]
SA	1254	M28 OVC	5		H	153	82	70	16	06		999	BINOVC 810 1200 69	TM
		72403 71606 58052 15328 72500 21810 63037											48469①	TM
SP	1337	M31 OVC	5		H				14	06		997	BINOVC	MJN
SA	1354	M31 OVC	8			143	82	70	18	07		996	BINOVC	MJN
SA	1456	M31 BKN 250 BKN	7			137	83	70	14	05		994		MJN
SA	1550	31 SCT 250-BKN	5		H	133	83	70	12	08		993	720 1201	MJN
SA	1655	44 SCT 250-BKN	5		H	133	82	69	14	08		993		MJN
SA	1755	44 SCT 55 SCT E250 BKN	6		H	137	80	70	15	03		994		MJN
SA	1854	E65 BKN 250 OVC	6		H	141	77	69	12	05		995	307 1201 84 RADAT 76132	MJN
SM	1900	72403 81205 59052 14125 62701 21307 63024											48469①	MJN
SA	1953	M50 BKN 250 OVC	7			144	76	69	12	06		996		MJN
SA	2054	49 SCT 75 SCT	7			147	74	68	12	06		997		MJN
SA	2152	45 SCT	10			147	73	68	13	06		997	107 1002	SRN
SA	2253	45 SCT	10			147	72	68	14	05		997		SRN
SA	2353	M45 BKN	10			153	71	68	15	04		999		SRN

FIGURE 4-1. FORM MF1-10A, SURFACE WEATHER OBSERVATIONS

-10B (4-79)	U.S. DEPARTMENT OF COMMERCE NOAA NATIONAL WEATHER SERVICE	STATION Washington, D.C. NWSO, Dulles Int'l Arpt.
SURFACE WEATHER OBSERVATIONS		DATE SEP 01 1981 · To convert LST to GMT ADD 5 hrs. SUBTRACT hrs.

Time (L.S.T.)	Station Pressure (Ins.)	Dry Bulb (°F)	Wet Bulb (°F)	Rel. Humidity (%)	Total Sky Cover	Lowest Layer Amt	Lowest Layer Type	Lowest Layer Height	Second Layer Amt	Second Layer Type	Second Layer Height	Summation Total	Third Layer Amt	Third Layer Type	Third Layer Height	Summation Total	Fourth Layer Amt	Fourth Layer Type	Fourth Layer Height	Total Opaque Sky Cover	Pressure Tendency	Net 3-hr. Change (Ins.)	Sunshine	Precipitation (Ins.)
00 53	29.670				10	5	Sc	28	4	Ac	E70	8	4	Ac	130	10				10	8	.010		
01 53	29.660				10															10				
02 53	29.655				10															10				
03 52	29.655				10	3	ST	9	10	Sc	M26	10								10	6	.015		
04 54	29.650				8															7				
05 53	29.665				10															10				
06 53	29.680				10	3	ST	8	3	Sc	38	5	6	Ac	E70	10				8	3	.025		
07 53	29.660				10															10				
08 53	29.660				10															10				
09 53	29.640				8	2	[illegible]	16	2	Sc	35	4	4	Ac	E70	8				7	5	.040		
10 53	29.630				7															7				
11 53	29.660				7															7				
12 [illegible]	29.640				10	10	Cu	M28												9	8	.030		
13 54	29.610				10															9				
14 56	29.590				8															6				
15 50	29.580				7	3	Cu	31	4	CI	200	7								3	7	.060		
16 55	29.580				8															3				
17 55	29.590				8															5				
18 54	29.600				10	7	Cu	E53	3	CI	200	10								7	3	.020		
19 53	29.610				10															7				
20 54	29.620				5															5				
21 52	29.620				3	3	Sc	45												3	1	.020		
22 53	29.620				1															1				
23 53	29.640				8															8				

SYNOPTIC OBSERVATIONS

Time (G.M.T.)	Time (L.S.T.)	No	Precip. (Ins.)	Snow Fall (Ins.)	Snow Depth (Ins.)	Max Temp. (°F)	Min. Temp. (°F)	Precip. Origin	State of Grnd.	51	52	53	54	55	Soil Temp.	57	58
	MID TO 0050	X	0	0	X	72	71	X	X						X		
	0050	1	T	0	0	75	71		1								
	0650	2	0	0	0	71	67		1								
	1250	3	0	0	0	84	70		1								
	1852	4	[illegible]	[illegible]	[illegible]	[illegible]	77		0								
	MID	X	0	0	0	77	71	X	X						X		

STATION PRESSURE COMPUTATIONS

Time (L.S.T.)	0052	0652	1252	1852
Att. Therm.				
Observ. Bar.				
Total Corr.				★
Sta. Press.	29.670	29.680	29.640	29.600
Barograph	29.665	29.665	29.630	29.580
Bar. Corr.	+.005	+.015	+.010	-.020

SUMMARY OF DAY (MIDNIGHT TO MIDNIGHT)

24-hr. Max Temp (°F)	24-hr. Min Temp (°F)	24-hr. Precip. Water Equiv. (Ins.)	24-hr. Snowfall Unmelted (Ins.)	Snow Depth (Ins.)	Peak Wind Speed (Kts.)	Peak Wind Direction	Peak Wind Time (L.S.T.)	Thickness of Ice on Water (Ins.)	Frozen Ground Layer Top	Frozen Ground Layer Base	River Gage	Sky Cover Sunrise to Sunset	Sky Cover Midnight to Midnight	Water Equiv. (Ins.)	81
84	69	0	0	0	11	5	1158					9	8		

WEATHER & OBSTRUCTIONS TO VISION

Type	Began	Ended	Type	Began	Ended
H	CONTD	1500			
F	0525	0630			
H	1545	1945			

REMARKS, NOTES AND MISCELLANEOUS PHENOMENA

TIME SUNRISE SUNSET

TOTAL SUNSHINE (MIN.) | PERCENT OF POSSIBLE SUNSHINE | CHARACTER OF SUNRISE | CHARACTER OF SUNSET

FASTEST OBSERVED 1 MINUTE WIND SPEED 9 M.P.H. OR FASTEST MILE M.P.H. ASSOCIATED DIRECTION 14 TIME 1655 EST ✓

TIME CHECK 0608:30 2 SEC SLOW / 1823:10 1 SEC SLOW /

★ BARO RESET TO ZERO CORRECTIONS.

✓ LAST OF SEVERAL OCCURRENCES

FIGURE 4-2. FORM MF1-10B, SURFACE WEATHER OBSERVATIONS

and 4-2 show the observations for September 1, 1981. The basic observations consist of those taken hourly, SA's, or Specials, SP's, which can be taken at any time. Observations are made in accordance with instructions contained in Federal Meteorological Handbook (FMH) No. 1. Surface Observations.

4.3 Data Analysis

Each hourly ALWOS observation was entered onto a blank MF1-10A form, along with the corresponding WSO observation, to form a daily comparison log. Although the Dulles observation is completed in advance of the ALWOS report (generally 5-7 minutes earlier), the two reports can be considered "simultaneous." In those cases where rapidly changing weather conditions resulted in obviously differing observations, appropriate considerations were made in data analysis. A sample portion of the log is shown in Figure 4-3. In column 1, H indicates "human observation" (WSO) and A indicates "ALWOS observation." Specials (SP) were included whenever any of the ALWOS observations, including those not "on the hour," differed in time within approximately the same number of minutes as the hourly observations.

As a means for comparing the WSO and ALWOS observations, a table of data tolerances was formulated based on consultations among personnel from T&ED, ISL, and the FAA. Figure 4-4 gives the ALWOS data tolerances with respect to the Dulles observations. As the evaluation proceeded, these tolerances were examined for suitability.

From the comparison log, the frequency of observations which were "out of tolerance" for a particular parameter was determined. Those observations out of tolerance were analyzed for possible cause(s) of discrepancy. Factors such as instrument and observer siting, prevailing meteorological conditions, and system operation were considered. In some cases, only a probable cause can be advanced for discrepant data. Some instances pointed to easily discernable factors. In any event, whenever a situation warranted additional investigation the circumstances were brought to the attention of ISL. Regular written status reports were provided to ISL and the FAA during the evaluation period.

4.4 Results

Figure 4-5 indicates the number of discrepant (according to the established tolerances) ALWOS observations by month and for the total evaluation period. The parameters covered are sky condition and cloud height, visibility, temperature, dew point, wind direction, wind speed, and altimeter setting. Precipitation and

WSO IAD/ALWOS

SURFACE WEATHER OBSERVATIONS

PAGE 2

SEP 1 1981

TYPE	TIME (LST)	SKY AND CEILING	VISIBILITY (SURFACE)	VISIBILITY (TOWER)	WEATHER AND OBSTRUCTIONS TO VISION	SEA LEVEL PRESSURE	TEMP	DEW POINT	WIND DIRECTION	WIND SPEED	WIND CHARACTER	ALTIMETER SETTING	REMARKS AND SUPPLEMENTAL CODED DATA
H	1254	M28 OVC	5		H		82	70	16	06		999	BINOVC
A	1800	NOT AVAILABLE											
SP H	1337	M31 OVC	5		H				14	06		997	BINOVC
A	1840	MISG	5						11	05		997	
H	1354	M31 OVC	8				82	70	18	07		996	BINOVC
A	1900	MISG	5				82	69	16	04		996	
H	1456	M31 BKN 250 BKN	7				83	70	14	05		994	
A	2000	MISG	5				83	69	15	04		993	
H	1550	31 SCT 250-BKN	5		H		83	70	12	08		993	
A	2100	MISG	7				83	68	13	05		992	
H	1655	44 SCT 250-BKN	5		H		82	69	14	08		993	
A	2200	MISG	7				82	67	16	05		993	
H	1755	44 SCT 55 SCT E250 BKN	6		H		80	70	15	03		994	
A	2300	MISG	8+				79	69	14	03		993	
H	1854	E55 BKN 250 OVC	6		H		77	69	12	05		995	
A	0000	MISG	8+				78	70	10	03		994	
H	1953	M50 BKN 250 OVC	7				76	69	12	06		996	
A	0100	CLR BLO 30	8+				77	69	10	04		996	
H	2054	49 SCT 75 SCT	7				74	68	12	06		997	
A	0200	CLR BLO 30	8+				74	68	14	03		997	
H	2152	45 SCT	10				73	68	13	06		997	
A	0300	CLR BLO 30	8+				73	69	14	05		997	
H	2253	45 SCT	10				72	68	14	05		997	
A	0400	CLR BLO 30	8+				72	70	00	00		996	
H	2353	M55 BKN	10				71	68	15	04		999	
A	0500	CLR BLO 30	8+				72	70	00	00		999	

FIGURE 4-3. ALWOS vs. DULLES OBSERVER COMPARISON LOG

Parameter	Tolerance
Sky Condition and Cloud Height	± 500 ft. and exact descriptor
Visibility	1/4 mi. (1/4-3 mi.) 1 mi. (3-8 mi.)
Temperature	± 3 degrees F
Dew Point	± 5 degrees F
Wind Direction	± 30 degrees (5 to 20 kts) ± 20 degrees (20 kts and up)
Wind Speed	±5 kts
Altimeter Setting	± .04" Hg.
Precipitation and Thunderstorm	exact descriptor

Figure 4-4. ALWOS DATA TOLERANCES

thunderstorm observations will be treated separately. A large number (4400) of observations were examined, which included both hourly and special reports. The numbers in parentheses are percentages. For sky condition and cloud height, a discrepancy was counted if either height or the descriptor was out of tolerance.

Figure 4-6 gives the number of observations which were output as "missing." Only hourly observations are included here. The figures are broken down into two main types of category, those representing cases where the entire ALWOS message was missing (TOTAL OBS column) and those indicating cases where partial parameters were missing (the remaining columns).

Apart from cloud and visibility observations, the number of discrepant reports are quite low. These two observations are among the more subjective as far as human observations are concerned, and are thus less easily compared with sensor-derived information. Other factors were also involved which contributed to the greater number of discrepancies, and these will be discussed later on. The numbers in Figure 4-5 for sky condition and cloud height are somewhat misleading. A great proportion (about 40%) of output cloud data from ALWOS was "missing" due to problems with the ceilometer (see Figure 4-6). A missing report was not counted as discrepant data but was included in the total possible observations. If the missing reports are excluded, the percentages of discrepant data would increase to 33%, 25%, 14%, and 27% for June - September, respectively, and to 23% for the total period.

Amounts of data reported as missing from ALWOS were also small (Figure 4-6) except for April when a significant number of complete observations were missing, and for the previously mentioned difficulty with the ceilometer. A complete listing of system and sensor malfunctions/failures and any corrective actions taken will be given in Section 4.4.2 As more experience with the system was gained and the "bugs" located and corrected, the numbers of missing complete observations and of most parameters decreased to almost nil the last 2 months. Overall, the percentage of complete observations missed was only 3% and for most of the individual parameters 2% or less. The notable exception was cloud data, where 38% of the total hourly observations were missing.

4.4.1 Parameter Discussions

Each parameter, or weather element, reported by ALWOS will now be discussed in further detail. Emphasis will be placed on both sensor performance and the observational algorithms. The intent of the evaluations is to attempt to relate the discrepant observations to a cause(s). No attempt was made to conduct a full scale sensor or algorithm evaluation, except where out of tolerance ALWOS observations could be ascribed to these areas. Some cases of discrepancy were obviously attributable to easily recognizable cause, but others required extensive invest   ions which were beyond the scope of the evaluation. In these instances suggested problem areas, solutions, etc., are often advanced. The ALWOS outputs are compared with those prescribed by FMH#1 wherever appropriate.

	No. OBS	SKY COND.& CLOUD HEIGHT*	VSBY*	TEMP	DEWP	WIND DIR	WIND SPEED	ALT
March	463	-	21(4)	13(3)	23(5)	5(1)	20(4)	1(0)
April	603	-	94(16)	9(1)	161(27)	10(2)	15(3)	1(0)
May	682	-	250(37)	6(1)	49(7)	14(2)	16(2)	1(0)
June	716	94(19)**	84(12)	4(1)	29(4)	3(0)	5(1)	0(0)
July	717	103(14)**	121(17)	2(0)	3(0)	5(1)	6(1)	0(0)
Aug.	816	117(14)**	123(15)	5(1)	1(0)	15(2)	2(0)	0(0)
Sept.	403	87(22)**	107(27)	1(0)	1(0)	7(2)	1(0)	0(0)
Total	4400	401(17)**	800(18)	40(1)	267(6)	59(1)	65(1)	3(0)

Note: * Total number of cloud observations sampled included a large proportion of missing observations. If these missing observations are exclude , the percentages of discrepancies change significantly . Visibility discrepancies reflect analysis of sensor siting and other factors. Further details are given in the appropriate text sections.

** Since the ALWOS ceilometer was not interfaced into the system until the June 10, 2200Z observation, a total of 2424 observations were involved, which included 488 in June. Percentages are based on these reduced figures.

FIGURE 4-5. ALWOS DATA DISCREPANCIES
(hourly and special observations)

	POSSIBLE OBS	TOTAL OBS	SKY COND. & CLOUD HEIGHT	VSBY	TEMP	DEWP	WIND DIR	WIND SPEED	ALT
March	480	9	-	1	2	2	2	0	9
April	720	118	-	1	10	11	7	1	6
May	744	9	-	14	28	28	24	22	19
June	720	15	203	6	3	3	1	1	13
July	744	2	273	7	24	24	27	26	4
Aug.	744	0	287	5	0	0	0	0	0
Sept	360	0	126	1	0	0	1	0	0
Total	4512	153	889	35	67	68	61	50	51

Note: Only 2330 total observations (specials not included) were possible for sky condition and cloud height, of which 482 were in June.

23 complete observations lost when output printer overprinted messages.

19 complete observations lost due to power interruptions.

10 complete observations lost due to planned system shutdowns.

FIGURE 4-6 MISSING AND PARTIALLY MISSING ALWOS DATA
(hourly observations only)

4.4.1.1. Sky Condition and Cloud Height

Overriding data collection was the excessive number of missing observations. The cause was established as the ceilometer's response to excessive heat buildup in its electronics as the outside temperature increased. Indeed, the missing data occurred almost exclusively during the daylight hours. Another contributing factor might have been the sun affecting the sensor's light detector. As temperatures began to decrease somewhat in September, slightly more data became available.

Figure 4-7 breaks down the discrepant ALWOS cloud observations. The first column indicates the number of observations where ALWOS reported no clouds at or below 3000 feet when the Dulles WSO reported clouds. The next column reverses the above situation. Next are the number of observations where both ALWOS and Dulles reported clouds and where the ALWOS data fell outside the prescribed tolerance for height and/or sky coverage descriptor. The last two columns indicate the number of observations where Dulles reported an obscuration at the surface and ALWOS did not and vice versa.

The great majority of cases where ALWOS failed to detect clouds occurred whenever there was a reduced visibility condition at the surface (precipitation, fog, haze). This tends to indicate that the laser receiver is not obtaining enough signal to detect clouds. In other words, the visibility phenomena is attenuating the laser return. All cloud height indicators have this problem to some extent.

The greater tendency for ALWOS to report surface obscurations may be traced to differences in ALWOS reported visibilities vs. the Dulles observer. As one of the criteria from the cloud algorithm (Appendix A) for determining obscurations, the visibility must be less than 1 1/2 miles. Due to significant differences in the location of the human observer and the visibility sensor, the ALWOS system tends to output lower visibilities in certain situations, thus contributing to the potential for more obscurations. There were also cases where ALWOS reported obscurations with visibilities as high as 2 miles, contrary to the algorithm specification. ALWOS also reports "total obscuration" much more frequently than "partial obscuration." Forty-eight observations were noted over the June - September period where Dulles reported partial obscuration and ALWOS responded with total obscuration, and only 1 case of the opposite situation. In fact, of the 176 ALWOS obscuration observations only 7 were partial obscurations.

Observations where both ALWOS and Dulles reported clouds at or below 3000 feet were examined to get a feel for whether the discrepant ALWOS reports were due to height, sky descriptor, or both. The results are given in Figure 4-8. Discrepancies in sky descriptor are considerably more common than those for cloud height. The height discrepancies were split about evenly as to whether ALWOS reported lower or higher heights than the Dulles observer (16 low and 20 high for the evaluation period). However, ALWOS reported less cloud amount more often than greater cloud amount, with 85 observations and 39 observations, respectively. Generally there was only one sky coverage category difference between ALWOS and Dulles, but some of the discrepant observations (13%) showed a two-category difference. An example of a 2 category difference would be ALWOS reporting a scattered (SCT) sky condition while the human reports overcast (OVC) conditions.

MONTH	ALWOS NO CLOUDS	DULLES NO CLOUDS	HEIGHT OR DESCRIPTOR	ALWOS NO OBSCUR.	DULLES NO OBSCUR.
June	26	1	1	0	13
July	20	2	36	21	24
August	14	1	52	8	42
September	17	1	55	4	10

FIGURE 4-7. ALWOS CLOUD DATA DISCREPANCIES
(For clouds reported at or below 3000 feet)

	NO. OBS	HEIGHT ALONE	DESCRIPTOR ALONE	BOTH
June	1	0	1	0
July	36	8	22	6
August	52	7	41	4
September	55	4	44	7
Total	144	19	108	17

FIGURE 4-8. ALWOS CLOUD HEIGHT AND SKY DESCRIPTOR DISCREPANCIES
(For clouds reported at or below 3000 feet)

4.4.1.2 Visibility

The interpretation of how discrepancies were counted should be explained, in particular how visibilities at the 3 mile "crossover" point were handled. As with each of the other parameters, the IAD observation is considered the "standard". If the human reported a higher visibility than the automated ovservation, then the following tolerances were in effect for the visibility comparisons:

human visibility is 1/4-3 mi., tolerance is ± 1/4 mi.

human visibility is 4-8 mi., tolerance is ± 1 mi.

Similarly, if the human observation was less than the automated, the following tolerances were used:

human visibility is 1/4 - 2 7/8 mi., tolerance is ± 1/4 mi.

human visibility is 3 - 8 mi., tolerance is ± 1 mi.

Analysis of visibility observations posed some special problems. Based upon the weather situation as reported by the Dulles observer and from observations taken by T&ED personnel, each comparison observation had to take into consideration the nature of the atmosphere that the visibility sensor was sampling as compared with what the human observer was viewing. Since the sensor was essentially at ground level, it was susceptible to conditions near the surface (fog, low lying moisture, e.g.) which the observer could see over or could not see at all. Thus, ALWOS would report lower visibilities in these instances. However, another type of obscuration, haze, often resulted in higher visibilities being reported by ALWOS. Possible explanations for these occurrences could be decreased sensitivity of the EG&G sensor to haze and increased vertical extent of the haze regime. Examining the airport transmissometer data aided in the determination of what type of visibility conditions were occurring at the surface. The small size of the visibility sensors sampling volume as opposed to the observer's large field of view is another major factor to consider when attempting to compare observations. The numbers of discrepant observations in Figure 4-5 reflect the attempt to analyze the above factors. If strict adherance to the tolerance limits set at the beginning of the test were followed, the figures would look worse for ALWOS. The total number of discrepancies then rises to 27%. Seventeen percent of the discrepancies reflected ALWOS visibilities lower and 10% higher than the observer.

Two significant problems surfaced which were believed to be sensor-related. Early in the evaluation period, intervals of considerable disagreement between ALWOS and the human were noted when relatively high winds (greater than 20 knots) with gusts (greater than 30 knots) were prevalent. The ALWOS would report visibility values much lower than the observer. Before and after the periods of poor agreement, wind speeds were considerably less. It was observed during these windy conditions that as gusts hit the sensor and the sensor "arms" were shaking, visibilities would lower. This apparent wind effect has been observed with the same type of sensor at T&ED and at the Air Force Geophysics Laboratory (AFGL) in Massachusetts. Though not much strong wind was encountered during the evaluation, roughly 25

observations were considered bad. Beginning in late April and continuing in May completely unrepresentative observations were output. This necessitated the replacement of the sensor with another similar unit. Though no specific cause for the poor obersvations was found, much better reports were noted following sensor replacement. Roughly 275 discrepancies in April and May were attributed to this problem.

The ALWOS system responded very well and in a timely manner to rapid changes in visibility. Agreement with the human observer in such instances was quite good. In some instances, the ALWOS responded more quickly than the observer was able.

Other noteworthy aspects of ALWOS performance which can be classified as relating to the algorithm/software portion of the system are:

a. Some totally unrealistic limits on "variable visibility" have been reported. As an example, 1/4V8 was output on April 30. Though the fault here lay with erratic sensor outputs, some form of quality control or sensor output damping is needed to avoid such false information going out as an observation.

b. The visibility algorithm (Appendix B) specifies that the limits of reported variable visibility must differ by more than 1/2 mile. Cases were noted where ALWOS was reporting limits of less than 1/2 mile difference, e.g., 1 5/8 V 1 7/8.

c. ALWOS does not add a "V" in the output message after the prevailing visibility whenever visibility is variable (as per FMH#1).

d. When the reported visibility was zero, there were occasions when succeeding visibility observations were reported as missing. Only 11 observations were lost. This flaw has been identified as a software "bug".

The ALWOS visibility tolerances were reviewed for possible improvement. Data was reexamined with the tolerance in the 1 to 3 mile range opened to 1/2 mile instead of 1/4 mile. Roughly a 10% improvement in the number of discrepant observations could be expected. No other changes in tolerance were considered appropriate.

4.4.1.3. Precipitation Occurrence

Times of beginning and ending of precipitation intervals as reported by ALWOS were compared with those reported by the Dulles observer. As the evaluation proceeded, many false indications (over 300) from ALWOS were noted. Sensor siting proved to be the major culprit. The precipitation Yes/No sensor was located on the roof of the WSO building, in close proximity to a very large air conditioning unit which was housed in another building. As part of the cooling process air is blown through circulating water, resulting in the production of numerous droplets. These droplets were then picked up by the wind and often deposited on the precipitation sensor, causing false responses. This necessitated the removal of the sensor and relocation to the center field instrument site in early July.

A second major source of false precipitation indication was due to a clock adjustment tone put out by Dulles Airport at around 56 minutes after each hour. The "noise" from the tone was triggering a false sensor indication. Over 100 observations were affected. A circuit on the sensor interface card was designed to eliminate the false indications.

Once the sources of erroneous data were detected and the associated problems remedied, a clearer picture of system performance was evident. It was not possible to totally verify many cases of precipitation indication without having an observer continuously monitoring exactly when precipitation began and ended in the immediate vicinity of the sensor. Of course, this approach is not feasible from a manpower standpoint. Conclusions and significant findings will now be summarized:

a. The sensor generally gives an accurate indication of rainfall. Over the entire evaluation period there were 8 instances where ALWOS failed to detect precipitation when reported by Dulles. However, in each instance only a trace of precipitation was reported by the observer for the total precipitation interval. In the period following movement of the sensor to center field and after the clock tone problem had been resolved, (from about mid-July onward), 17 instances of false precipitation indication were recorded. Whether these were due to false sensor output or system difficulties could not be determined. Some cases involved only one minute's precipitation duration. The NWS Test and Evaluation Division conducted an extensive field evaluation of the precipitation sensor[3] for about 10 months and noticed a negligible number of false sensor hits. Data collection was not performed in an automated mode.

b. The earlier T&ED evaluation indicated that the sensor performance degrades in snow as opposed to rain. In cases of snow which occurred in the ALWOS evaluation, the human reported the event with considerably more accuracy than did ALWOS.

c ALWOS reported the beginning of precipitation earlier than the WSO observer in many instances. Though impossible to verify in most cases, based upon the T&ED evaluation and from spot checks during the ALWOS evaluation, the earlier starting times are probably valid. The sensor is capable of responding to individual water drops and thus can accurately indicate the initial stages of a precipitation event which may not be detected by an observer in some instances. No pattern was noticeable with respect to ending times.

d. As the algorithm is written, in order to satisfy the FMH#1 criterion for denoting individual precipitation periods (at least 15 minutes between intervals), report-

3. Final Report: Evaluation of Mechanical Precipitation Occurrence Sensors, T&ED Division Report No. 2-80, May 1980.

ing the ending of precipitation (the last sensor indication) is delayed 15 minutes. Some confusing remarks are the result. For example, if the last sensor indication occurs at 1050Z, the program would wait the 15-minute period before reporting and would then report PE50 in the 1120Z ALWOS observation instead of in the normal (according to FMH#1) 1100Z hourly observation. The PE50 remark would then be carried in the next ALWOS output message (1140Z) and appear in the 1200Z hourly as well, even though the precipitation ended 1 hour and 10 minutes earlier. A remark could be output at 1200Z such as PE50B20 where the PE50 would actually stand for 1050Z and the B20 for 1120Z.

e. Whenever precipitation remarks were reported in an hourly ALWOS observation (e.g., PB20) and precipitation was occurring at the time of the observation, a "P" was not output.

f. Infrequently a precipitation interval would have either the beginning or ending time remark absent from the appropriate ALWOS observation.

4.4.1.4 Thunderstorm Occurrence

Analysis of thunderstorm occurrence as reported by ALWOS was limited in many instances due to the capabilities of the lightning detector. Since the sensor is capable of detecting lightning beyond the visible and audible range of the observer at Dulles, comparing ALWOS vs. Dulles observations on a one-to-one basis was impossible. This increased sensor capability (out to about 50 miles) was determined from an evaluation of the same sensor at T&ED[4]. Many cases arose where ALWOS reported thunderstorm activity and the Dulles observer did not, as well as numerous instances where ALWOS reported earlier beginning and later ending times.

In order to reconcile this potential problem, radar reports from the NWS Patuxent River radar were examined and ALWOS thunderstorm reports evaluated accordingly. The reports consisted of verbal and coded messages received on teletype at T&ED. However, some reports could not clarify whether the lightning detector was giving a valid indication or responding to electronic "noise" or some other triggering mechanism.

The T&ED evaluation showed that the sensor was indeed quite susceptible to such "noise", which resulted in false lightning indications. During the Dulles evaluation through June, there were 114 instances of false indication. However, from July 1 through September 15 only 3 such cases were noted. No specific cause could be found for the improved performance.

In only one instance did the ALWOS fail to detect a thunderstorm event when reported by the human observer.

4. Evaluation of the Atlantic Scientific Lightning Warning System FCM-1, T&ED Division Report No. 1-80, January 1980

According to FMH#1. a thunderstorm is considered to have ended 15 minutes after the last determined occurrence. This ensures that thun'erstorm events will last at least 15 minutes. The ALWOS algorithm does not make provision for such reporting and often thunderstorm intervals were less than 15 minutes. As a result, remarks such as TB05 E10 were reported by ALWOS.

4.4.1.5 Temperature

Few discrepant observations were reported by ALWOS. No additional comments are necessary.

4.4.1.6 Dew Point

ALWOS dew points presented a problem early in the evaluation period, particularly in April. A significant number of ALWOS observations had fallen out of the tolerance limit, on the low side, and were not consistent with the synoptic weather situation. For example, during fog episodes the dew point spreads (the difference between the ambient temperature and dew point temperature) reported by the Dulles observer were often 2 degrees or less, appropriate values for fog conditions. The ALWOS would report dew point spreads of 5-7 degrees which are unrepresentative of fogs.

The dew point bobbin assembly had to be replaced twice to correct the deficiency. After the last replaacement, in early May, readings became much more consistent and within tolerance for the great majority of remaining observations.

4.4.1.7 Wind Direction and Speed

Both parameters were reported by ALWOS with few discrepancies. Cases where winds were "light and variable" were not considered in the ALWOS vs. Dulles comparisons. As defined by FMH#1, "light winds are those where the wind speed is 6 knots or less, and a "variable" situation exists when the wind direction fluctuates by 60 degrees or more during the period of observation.

4.4.1.8 Altimeter Setting

Altimeter setting was the most consistent and accurate parameter measured by ALWOS. Only 3 observations were out of tolerance.

4.4.2 System/Sensor Problems

In Figures 4-9 and 4-10 the significant ALWOS malfunctions/"bugs" which surfaced during the evaluation period are listed in chronological order. Each item is described as to date first observed or reported, the nature of difficulty, and any corrective measures taken. Problems are grouped according to whether they were system (data acquisition, software, algorithms, etc.) or sensor-related.

The majority of missing or invalid data is accounted for by the failures indicated in the two listings. "Analog to digital" (A/D) errors were the major sources of poor or missing data. The number of sensor difficulties was minimal, but most cases involved a serious degredation or loss of ALWOS data which required replacement of faulty sensors.

Date	Problem	Corrective Action
3/13/81	Numerous system restarts caused by faulty low voltage detection card	Disconnected low voltage detection card
3/13/81	Erratic operation of ALWOS system clock caused by airport's clock adjustment tones placed on A/C power lines.	Installed crystal oscillator as time base for ALWOS system clock in place of 60 Hz. line frequency.
3/31/81	Suspected heat problem in remote A/D box causing missing data	Removed innermost door of the remote A/D converter to allow heat to escape to the vented outer box
4/13/81	Suspected high humidity conditions in remote A/D box causing missing data	Put inside door back on the A/D box
4/23/81	A/D errors continue	Fan installed to cool A/D box
5/22/81	Large number of A/D errors due to high temperature reference voltage	Replaced reference voltage card
5/28/81	High dew point reference voltage causing A/D errors	Replaced reference voltage card
6/15/81	When actual visibility was close to zero, "M" occasionally reported in the output message (software problem)	No action taken
6/22/81	Visibility sensor inoperative due to lightning strike	Installed ground wires and replaced an output integrated circuit
7/06/81	Clock adjustment tones are causing precipitation Yes/No sensor to trigger falsely	Circuit designed to require a longer time constant from sensor's contact closure before indicating an output
7/29/81	Lightning apparently knocked out the remote A/D system. Lightning arrestor had shorted out	Removed shorted lightning arrestor
7/29/81	A/D errors due to varying voltage from "+5V" power supply	Changed power supply in A/D box

FIGURE 4-9. ALWOS SYSTEM MALFUNCTIONS

Date	Problem	Corrective Action
3/17/81	Low visibilities output during high winds (with gusts) due to shaking of sensor "arms"	Installed bolt holding sensor on its stand but sensor apparently was still vulnerable to high wind conditions
4/10/81	Dew points too low	Replaced sensor bobbin assembly
4/28/81	Visibilities becoming totally unrealistic	Replaced sensor
6/10/81	Ceilometer outputting considerable amounts of missing data due to heat build-up and sunlight possibly affecting sensor light detector	New sensor ordered from Impulsphysik. Did not arrive in time to be installed in system before conclusion of evaluation period.

FIGURE 4-10. ALWOS SENSOR MALFUNCTIONS

5. SUMMARY AND CONCLUSIONS

An ALWOS system located at the Dulles International Airport was evaluated for a six-month period under operational-type conditions. Observations output from ALWOS were compared with official NWS observations taken at the Dulles WSO. The weather parameters observed included sky condition/cloud height, visibility, temperature/dew point, wind speed/direction, altimeter setting, precipitation occurrence, and thunderstorm (lightning) occurrence. Comparison with NWS data was generally limited to the regular hourly observations taken at Dulles. Those parameters, as reported by ALWOS, which were outside of prescribed data tolerance limits were examined for the cause(s) of discrepancy.

Based on the field evaluation of the ALWOS system, the following points should be emphasized:

a. The ALWOS as configured at Dulles Airport is a workable system which can provide an automatic weather observation from the data acquisition, processing and display point of view, with the potential for good long-term system reliability. After a period of familiarization with the equipment and dealing with an assortment of system and sensor problems, the functioning of the system became relatively trouble-free. Problems with A/D data conversion were reduced to minimal levels during the latter months of the evaluation.

b. Evaluation of the ALWOS supports the already generally accepted concept that *automated*, low-cost weather observation systems can indeed perform such a function given suitable sensing devices. Though printed as a hard-copy message every 20 minutes, ALWOS information was provided also in one-minute update form, including "voice" output, which lends itself to automated application.

c. Performance of some of the various ALWOS sensors reinforces the important and still basically unfulfilled need for suitable instruments which can supply information that can be successfully incorporated into an automated observing scheme. This is particularly true for cloud, visibility, and thunderstorm detection data. The Impulsphysik prototype ceilometer was unacceptable due to its consistently large output of missing data. The EG&G visibility sensor suffered from a period of serious unreliability (which eventually required replacement of the sensor). Atlantic Scientific's lightning detector as designed was unsuitable for human vs. machine comparisons and also displayed a high false alarm rate, at least during the early months of the evaluation. Finally, the YSI dew point element (bobbin) required replacement to correct consistently low readings.

d. Temperature, wind direction/speed, and altimeter setting observations were usually within tolerance limits. When the sensor was operating properly, dew point temperatures

also were generally within tolerance. Precipitation Yes/No was handled reasonably well by the Wong Laboratories grid sensor. With proper sensor operation, reported ALWOS visibilities showed reasonable agreement with the human observer in many instances. but sensor location introduced a source of significant disagreement under certain visibility conditions.

e. It was not within the scope of the evaluation effort to thoroughly review the performance of the parameter algorithms. Algorithms were examined to the extent where discrepant ALWOS observations, inconsistencies in reporting, etc., were caused by the algorithms themselves or the manner in which the algorithms were programmed into the system. Such determinations have been described in earlier sections of this report.

Two algorithms, for clouds and visibility, have had considerable review and testing performed on them in other automated systems and are included in Appendices A and B, respectively. Other algorithms, for example those for precipitation and thunderstorm occurrence, have received less scrutiny.

6. ACKNOWLEDGMENTS

Several people from the National Weather Service and the Federal Aviation Administration were involved in the development and testing of ALWOS at Dulles Airport. Personnel from NWS's Integrated Systems Laboratory, particularly Ralph Ruth, Warren Blanchard, John Shaffer, John Nilsen, Don Edmonds, Bill Billingsley and Don Clippinger performed the large task of system hardware/software development, integration and installation at Dulles Airport. Data collection and analysis of the six months of test data were performed admirably by Ray Choffe and John Blelloch of NWS's Test and Evaluation Division, Responsible for successfully coordinating the efforts of both agencies were Ray Colao, Dave Floyd and Carroll Workman of the Federal Aviation Administration and Richard Reynolds, Jim Cunningham and Kenneth Shreeve of the National Weather Service. The installation and operation of the ALWOS system at Dulles would not have been possible without the assistance and cooperation of NWS weather observers and FAA technical personnel located at the airport.

Note: This report is furnished for technical information only. The National Oceanic and Atmospheric Administration (NOAA) does not approve, recommend or endorse any product; and the test and evaluation results shall not be used in advertising, sales promotion, or to indicate in any manner, either implicitly or explicitly, endorsement of the product by NOAA or the National Weather Service.

APPENDIX A

ALWOS CLOUD ALGORITHMS

AD-A117 447 NATIONAL WEATHER SERVICE SILVER SPRING MD F/G 4/2
AUTOMATED LOW-COST WEATHER OBSERVATION SYSTEM (ALWOS).(U)
FEB 82 W HUFFMAN, S IMBEMBO

UNCLASSIFIED DOT/FAA/RD-82/31 NL

2 of 2

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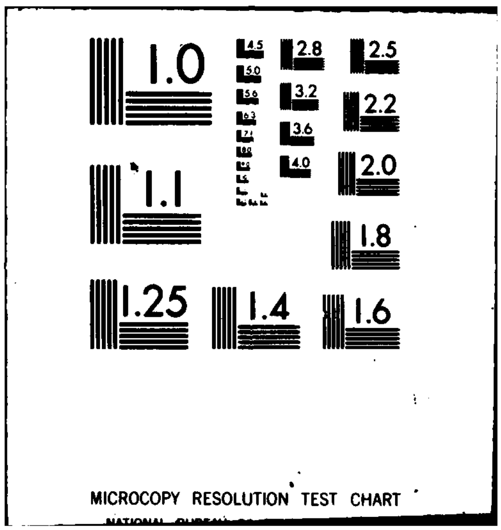
1.0
4.5
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1.8
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MICROCOPY RESOLUTION TEST CHART

ALWOS CLOUD ALGORITHMS

CLOUD BASE HEIGHT ALGORITHM

&

AUTOB ALGORITHM (Revised)

October 1, 1980

Ceilometer CPU Description

The following is a description of the Ceilometer CPU that will operate in the ALWOS System. The Ceilometer CPU accepts the Impulsphysic ceilometer data and outputs cloud cover via the ceilometer CPU software. The CPU software is made up of the AUTOB algorithm modified to work with the Impulsphysics ceilometer. The major modification to the AUTOB algorithm is in Cloud Height Algorithm which is described next.

Cloud Base Height Algorithm

Description: This module is entered from the AUTOB Algorithm which has been modified for ALWOS. The Cloud Base Height Algorithm accepts the data from the Impulsphysic Ceilometer which consists of 65 words. The first and last words are start and stop codes, words two and three are status words, and the remaining 61 words contain the backscattered energy. These words in position 4-64 inclusive correspond to range bins 100-150 feet to 3100-3150 feet (n=4 to n=64). Each word consists of 8 bits or one byte and can vary from 0 to 255. The backscattered energy data d_n, in the n^{th} range bin, is offset by 13 in the hardware. Let $D_n = d_n - 13$ where D_n now consists of signals S_n plus noise E_n, $D_n = S_n + E_n$. The noise in each range bin, E_n, is drawn from a normal population with mean 0 and variance $N_n \sigma_1^2$, where N_n is

the number of laser pulses summed to form the estimate of D_n and σ_1^2 is the noise variance for a single pulse. (Note that N_n increases with n to make up for the $1/R^2$ range loss). Thus $\sum_{n=4}^{64} \sigma_n^2$ is an estimator of $\sum_{n=4}^{64} N_n \sigma_1^2 = \sigma_1^2 \sum_{n=4}^{64} N_n$. We observe signal plus noise. Since S_n is always positive, if one forms the partial sums from each range bin m for which D_n is negative, then a conservative (small) estimator of σ_1^2, is $\hat{\sigma}_1^2 = \sum_{m=4}^{64} D_m^2 / \sum_{m=4}^{64} N_m$. The ratio $(D_n - 1)/\hat{\sigma}_n = (D_n - 1)/n\,\hat{\sigma}_1 = R_n$ is then formed, with the understanding that $n \simeq N_n^{1/2}$. If $R_n \geq 2.0$, which is to say that the corresponding D_n is two or more standard deviations above the noise, for three or more successive n's, then choose the first bin where $R_n \geq 2$ as the cloud base height.

Ceilometer CPU Memory

The ceilometer algorithm as implemented uses the AUTOB algorithm preceded by the Cloud Base Height algorithm previously described. The AUTOB algorithm is documented in "AUTOB Algorithm #2" and will not be described here. The AUTOB algorithm was developed before we had the Intel development systems, and is not relocatable. The code for AUTOB is not memory compatible with the 8020 Intel CPU board. Two alternatives to correct this problem were to either type 2.5K of code into the MDS, including reassignment of subroutines previously in absolute addresses, or rearrange the 8020 board memory to be compatible with AUTOB. The

latter approach was taken. The decision was made because it would be time consuming to re-debug the AUTOB algorithm after a lengthy conversion. The memory rearranging required placing the 8020 RAM at 1000H instead of 3000H and placing the AUTOB algorithm and the Cloud Base Height algorithm in the absolute code areas of 0 to 0FFFH and 1800H to 1FFFH, RAM memory being at 1000H to 17FFH. This was accomplished quite painfully since it required relocating some of the floating point by hand. The following is a memory map of the Ceilometer CPU.

0000 to 09FFH	AUTOB Algorithm #2
0A00H to 0ED0H	Cloud Base Height Algorithm
0EF8H to 0FFFH	Floating Point
1000H to 17FFH	RAM
1800H to 1FFFH	Floating Point

The AUTOB algorithm has been slightly modified for ALWOS. These include modifications of the Baudot codes to ASCII codes, modification of the inputting of visibility and outputting of cloud cover, and addition of special status and control codes. These changes are described elsewhere in this document.

Ceilometer CPU Interfacing

The Ceilometer CPU accepts data from the Impulsephysic Ceilometer at 110 baud, RS232 format. The signal is input on J3-4 and gnd. The signal occurs every 28 seconds and consists of 65 words.

The remaining interfacing to the CPU card is accomplished via the multibus. The CPU inputs visibility data from the main CPU and outputs cloud cover data to the main CPU. The visibility data is stored at location 832AH by the main CPU, busy/done logic is not required for this transfer because it is a one instruction store by the main CPU. The visibility is stored as a "displacement number" defined as follows:

=15:	visibility = 1 1/2 miles
<15:	visibility > 1 1/2 miles
≥15:	visibility ≤ 1 1/2 miles
=FFH:	visibility is missing

Ceilometer CPU Error Messages

As mentioned previously the first word in the stored ceilometer message is either 01 or 02. The 02 indicates that the ceilometer message that follows is good. An 01 indicates that the ceilometer is not working due to any one of the following conditions:

- The laser power is not within 60 $\pm$ 10% of its maximum output power.

- The laser is not outputting a message at least every 40 seconds.

- The data in the 61 backscattered energy bins has no negative numbers or that no noise is present in the ceilometer signal.

In all of the above conditions the CPU will not lockup in the error mode. Should any of the error conditions correct itself the CPU will continue to develop a cloud message.

Cloud Base Height Algorithm Subroutines

The Cloud Base Height algorithm (CBH algorithm) uses subroutines to input data from the UART, check data start and complete codes, and check data quality. These subroutines are annotated in the program listing and further explanation here would be redundant. The major subroutines used in the CBH algorithm are the Floating Point Arithmetic Library or FPAL. This is a software package provided by Intel. The operations used are addition, multiplication, division, value comparison, and conversion from decimal to floating point numbers. All operations are single precision with a range of 1.2×10^{-38} to 3.4×10^{38}, using a 32 bit format. The details of FPAL can be found in the Intel manual entitled "8080/8085 Floating-Point Arithmetic Library User's Manual."

Program Flow:

- Call from the AUTOB algorithm

- Initialize the stack, setup UART, general housekeeping

- Look for start character from ceilometer, lock onto data stream

- Check laser power within limits of 60 ± 10%, if out of limits, place 01 in place of 02 at message start

- Input 61 bins of data in CBUF buffer, data stored is minus the 13 offset. Store negative data in MBUF followed by bin number corresponding to negative number.

- Take the sum of the squared negative numbers in MBUF

$$\sum_{m=4}^{64} D_m^2$$

- Convert the bin number stored in MBUF to number of samples in that bin. Sum number of hits for all of negative numbers

$$\sum_{m=4}^{64} N_m$$

- Form the estimated noise $\hat{\sigma}_i = \left[\sum_{m=4}^{64} D_m^2 \Big/ \sum_{m=4}^{64} N_m\right]^{1/2}$

which is defined as SIG. The square root of a number x^2 is determined by iterating the expression

$$x_{n+1} = 0.5(x_n + x^2/x_n)$$

n=1,2,3,... until $|x_{n+1} - x_n|$ is sufficiently small, or in other words, until x_{n+1} is a satisfactory approximation to $x = (x^2)^{1/2}$. As an initial guess, $x_1 = 1$.

- Determine the number of standard deviations above the noise $R_n = (D_n - 1)/(n\ \mathrm{SIG})$ for each bin

- If the number of standard deviations ≥ 2 for three successive bins, record the magnitude of the third standard deviation and first cloud height where the standard deviation ≥ 2.

- Add 96H to the cloud height value to be compatible with AUTOB algorithm and return to AUTOB algorithm.

AUTOB DESIGN ALGORITHM #2

March 31, 1977

Observation Techniques Development & Test Branch

Test and Evaluation Division

Sterling, Virginia

REVISED FOR ALWOS   SEPTEMBER, 1980

Equipment Development Laboratory

Silver Spring, Maryland

AUTOB DESIGN ALGORITHM #2

This updated algorithm is intended to replace the AUTOB cloud algorithm presently in use at Summit, Alaska; Wendover, Utah; and SR&DC, Virginia. It recognizes the current limitations and constraints on programming, computer sizing, and hardware as discussed by T&ED, DSD, and EDL at the AUTOB meeting on March 25, 1977.

The inputs to the algorithm are:

1. Impulsphysic laser ceilometer

2. Sensor Equivalent Visibility

The operating conditions are:

<u>Clouds</u>

1. The Impulsphysic laser ceilometer will be the cloud sensor.

2. Input to the algorithm will be digitized back-scattered energy for each 50 foot range bin and a total range of 100 to 3100 feet.

3. One total range scan every 28 seconds will be used.

4. Update cloud information approximately every 4 minutes.

5. There will be only one cloud height (lowest return) each scan.

6. Any cloud return below 100 feet will be rejected as a "no hit".

7. Upper limit of cloud returns will be 3000 feet.

ility

1. Visibility (sensor equivalent visibility) is derived from the ALWOS visibility algorithm (described in a separate document).

2. An indication of present visibility below 1 1/2 miles is used as input to the cloud algorithm.

NOTES:

1. Data from the cloud algorithm and the backscatter visibility module are nonsynchronous. (This will occasionally cause an obscuration to be reported with a present visibility of 2 or more miles).

2. Each sample is counted as three samples when it is entered in the AUTOB algorithm. This is done to account for the slower data rate of the Impulsphysic ceilometer as compared to the Rotating Beam Ceilometer (RBC). This results in fifty actual data points (150 data points when counted three times) over a period of approximately 23 minutes being used to compute cloud cover.

AUTOB DESIGN ALGORITHM #2

PROCESSING SEQUENCE

1. From the Impulsphysic laser ceilometer, retain a time ordered sequence in such a way that a running 23 minute sequence of strikes is available on demand for processing.

2. Sample the ceilometer every 28 seconds for 23 minutes. There will be only one cloud height (lowest return) per scan.

3. Convert each sample to cloud height in feet. Cloud hits reported as above 3000 feet are to be considered as no hits.

4. Recency weighting. Give double weight to each scan in last 1/3 of sample interval (e.g. last 10 minutes). That is if there are, say, hits within the last 10 minutes at 2500, 2550, and 2800 feet, we would consider them to be 2500, 2500, 2550, 2550, 2800, and 2800. Likewise, "no hits" would also have double value. Total possible hits are thus three times the total ceilometer scans plus total scans in last 1/3 of sample period. (E.g. for 23.3 min. we have 50 scans x3 (each scan weighted 3 times) plus 50 = 200 scans or possible hits.) These double weights are to be carried through remainder of program.

5. Bin each sample hit to nearest 100 feet.

6. If cloud hits are present in more than 5 bins, use Cluster Subprogram in attached supplement. Output consists of cluster heights and number of hits in each cluster. Go to Step 8 of algorithm.

7. If hits are confined to 5 bins or less, go directly to combine subprogram. Each bin will now be considered an individual cluster. Output consists of cluster (bin) heights and number of hits in each cluster.

8. Combine Subprogram:

   a. Order all clusters from lowest to highest.

   b. Start from lowest cluster and search upward.

   c. If two clusters fit the following table:

Lower Cluster Height	Higher Cluster Within
Surface to 500 feet	± 150 feet
500 to 2000 feet	± 250 feet
2000 to 3000 feet	± 350 feet
	of lower cluster height

Then we would combine:

d. Combine by taking the height of the lower cluster times the number of hits in that cluster plus the height of the higher cluster times the number of hits in that cluster and divide total by the sum of the number of hits in both clusters.
(e.g. (a N + b M + c H)/(N + M + H)). This value is now our new cluster height value, and (N + M + H) is number of hits in that cluster.

e. Once two clusters have been combined, they cannot be separated and are to be considered a new cluster which will be placed in the proper sequence of remaining clusters.

f. Cycle until all possible clusters are combined.

9. Each cluster with more than 5 hits is considered a layer. Each cluster with 5 or less hits and whose ascribed height is lower than the lowest cluster with more than 5 hits is not considered any further in the program and its number of hits is not added to any other cluster. For those clusters with 5 or less hits, and whose ascribed height is higher than a cluster with more than 5 hits, these clusters are not considered any further but their hits are added to the next higher cluster; however, the highest cluster will be considered a layer even with only one hit.

10. For each assigned height value round to the nearest 100 feet.

11. For each cluster, divide number of hits in that cluster by total possible hits. Assign this result to R(I) for each respective cluster. The cumulative frequency ratio (CR) will be summation of the R(I)'s up to cluster (I).

12. Output shall consist of standard information on cloud condition. This output group will be one, two, or three statements of sky conditions as follows:

    a. CLR BLO 30 if less than .05 cumulative frequency ratio (CR) exists for all height ranges and output is not modified by Step 13.

    b. If any height range (layer) has a cumulative frequency ratio (CR) of .05 or higher, calculate hchcScScSc for each layer having a cumulative frequency ratio of .05 or higher, where: hchc = cloud heights to nearest reportable increment as determined above and ScScSc is one of the following contractions:

        SCT, BKN, or OVC where:

SCT = a cumulative frequency ratio of $.05$ to $< .55$

BKN = a cumulative frequency ratio of $.55$ to $< .87$

OVC = a cumulative frequency ratio of $\geq .87$

c. The output group shall consist of one, two, or three statements of sky conditions starting with the lowest such height range as follows:

hchcScScSc   hchcScScSc   hchcScScSc

The following priorities shall be used in determining which of one, two, or three height ranges will provide data for the standard group:

(1) The lowest height range for which the (CR) equals or exceeds .05.

(2) The lowest height range at which the (CR) equals or exceeds .55 if different from (1) above.

(3) The lowest height range at which the (CR) equals or exceeds .87 if different from above.

(4) The second lowest height range where (CR) is greater or equal to .05 and less than .87.

(5) The highest height range where (CR) is greater or equal to .05 and less than .87.

(6) A second (higher) overcast (CR .87) is not reported. However the remark HIR CLDS VSBL is output at the end of the AUTOB message.

13. If the visibility, as furnished from elsewhere in the program, is less than 1 1/2 miles, scan last 10 minutes of cloud data.

a. If there are less than 5 hits in the last 10 minutes disregard the computations in Step 12, and output as the sky condition:

WX.

b. If there are 5 or more hits, prefix cloud/cover amount with -X. Also add .6 cloud coverage to lowest (and subsequent) cloud layers generated by program and recompute cloud layer amounts. Recompute and relabel cloud layer designations (SCT,BKN) with new factor of .6 added.

c. If the output from Step 12 is CLR BLO 30 , change this output to read -X.

14. a. When it has been determined which cloud data are to be reported, these data will be ordered in the value of hchc starting with the lowest hchc value.

b. For lowest BKN or OVC layer only, prefix height value with an E (e.g. E 12 BKN).

15. Print out cloud observation.

16. Recycle program every 4 minutes.

CLUSTER SUPPLEMENT

Independently for each ceilometer:

1. Collect the cloud height as given by each ceilometer measurement.

2. Order all the cloud heights in ascending order.

3*. Compute the least square distance between any two heights by

$$D = (N(J)*N(K)/(NQ)+N(K))*(H(J)-H(K))$$

where: D = Least square distance

N(J) = Number of readings in the first cluster

N(K) = Number of readings in the cluster immediately following

H(J) = Computed mean height for cluster (J)

H(K) = Computed mean height for cluster (K)

4. Combine the pair of clusters that have the least squared distance by

$$H(J) = (N(J)*H(J) + N(K)*H(K))/(N(J) + N(K))$$

where variables are as defined in Step 3.

5. Compute pooled standard variance by $P2 = P2 + D /(N-1)$ where:

*P2 = Pooled standard variance

N = Number of cloud heights measured in Step 1.

6. Move all clusters down 1 position starting from H(K+1)

i.e. $H(K) = H(K+1)$ and $N(K) = N(K+1)$.

7. Repeat Steps 3 thru 6 until only 5 clusters remain.

8. Repeat Steps 3 thru 6 until only 1 cluster remains or when square root of P2 is greater than 3 times the value of the square root of P2 at 5 clusters.

9. The total number of clusters is the number remaining when Step 8 is true.

---

* The first time thru this routine N(J) and N(K) are equal to 1. P2 is initialized to 0.

APPENDIX B

VISIBILITY ALGORITHM (SINGLE SENSOR)

T&ED REPORT No. 5-80

TEST & EVALUATION DIVISION REPORT NO. 5-80

SINGLE SENSOR VISIBILITY ALGORITHM

CONTINUOUS DISPLAY MODE

SECTION A

Introduction

Visibility is the most difficult of the subjective observation parameters to automate since it is the attempt to logically define a human's personal visual impressions. However, by using the technique of "sensor equivalent visibility" (SEV), developed by George and Lefkowitz (1972), we have been able, by processing measurements from a network of sensors, to produce a substitute for human visibility.

SEV is defined as any equivalent of human visibility derived from instrumental measurements. In practice, the sensor from which SEV is derived almost always requires uniform visibility for an accurate calibration. Once a sensor is calibrated under uniform visibility conditions, it can then be used to determine visibility under nonuniform conditions. The processing strategies for using the SEV's from individual or multiple sensors to approximate human visibility under nonuniform visibility conditions were the subject of Aviation Automated Observation System (AV-AWOS) experiments (NOAA/National Weather Service, 1979).

Federal Meteorological Handbook #1 (FMH #1) (NOAA/National Weather Service, 1979) specifies the manner in which human observations of visibility are to be taken and reported. It defines prevailing visibility (PV) as, "The greatest visibility equaled or exceeded throughout at least half of the horizon circle which need not necessarily be continuous." PV is determined at the usual site(s) of observation or from the control tower level during low visibility conditions.

SEV and PV have different principles of observation. SEV is based on sensor measurement of a small volume sample with extrapolation to overall areal visibility. PV, as determined by a human, relies on sensory information obtained over a relatively extensive area. SEV, based on a point sensor, usually has strongest relationships with PV during homogeneous conditions. However,

is sufficiently strong correlation in periods of nonuniform conditions rrant substituting instrumental visibility for human visibility.

This algorithm is based upon the visibility algorithm developed during /-AWOS experiment. The underlying assumption was that while a vast net- of (point) visibility sensors would be needed to perfectly replicate the scribed by the human observer, a smaller network could give an adequate iption. From the results of the AV-AWOS experiment, we have specified ie general site configuration a three sensor network with PV defined as entral value of this three sensor visibility network.

The AV-AWOS experiments also showed that there was close agreement, in cases, among the output visibilities from each of the three sensor sites. result, the PAMOS committee has recommended that for an automated system efinition of PV be changed to: "That horizontal visibility near the 's surface representative of the visibility conditions in the vicinity of oint of observation or measurement; (Eggert, 1980), and that the current ition of PV be the method or procedure used by the human observer to pro- is visual observation.

Using the new definition of PV we are now able to determine, after an idual site survey, whether one visibility sensor can adequately describe any particular site. Our experiences at Dulles International Airport and Patrick Henry International Airport (PHF) have pointed up the need ite surveys before installing sensor networks at airports. The primary e of a detailed site survey is to identify unique conditions that might nce judgments on the number of sensors needed and configuration.

We have produced three options of our visibility algorithm:

Option 1: <u>Single sensor visibility algorithm, continuous display mode</u>.

This algorithm is the single sensor AV-AWOS algorithm designed to be updated each minute on the various displays and has the capability of detecting and reporting Special Observations.

Option 2: <u>Three sensor visibility algorithm, continuous display mode</u>.

This algorithm is the same as Option 1 but uses three sensors to determine prevailing visibility.

Option 3: This algorithm also computes a new visibility value each minute but only displays a new value on demand. There are no provisions for Specials, and the algorithm provides for only one remark of variable visibility. This option is similar to the current AUTOB operation.

The enclosed algorithm is for the single sensor continuous display mode of operation.

References

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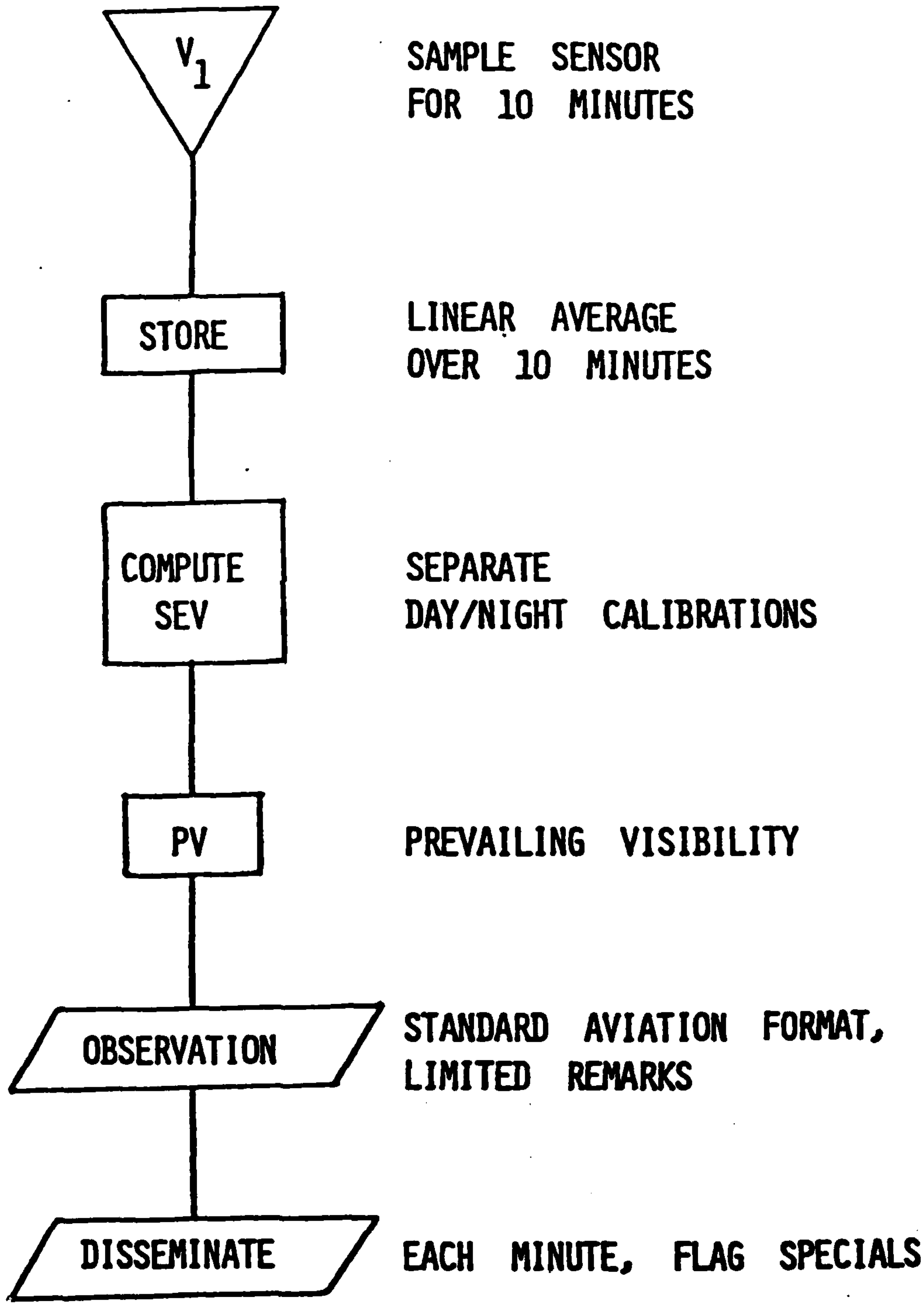
NOAA/National Weather Service, 1979: Federal Meteorological Handbook No. 1, Surface Observations, U. S. Government Printing Office, Washington, D. C.

NOAA/National Weather Service, 1979: Aviation Automated Observation System (AV-AWOS). Prepared for: U. S. Department of Transportation, FAA. Report No. FAA-RD-79-63, 131 pp.

Eggert, William E., 1980: Definitions of Weather Parameters for Interagency Use. Memo to members of PAMOS Working Group.

SINGLE SENSOR VISIBILITY ALGORITHM
(CONTINUOUS DISPLAY MODE)



1. Visibility

The system shall include provisions for determing a representative visibility for a selected area. The reportable visibility values will range from 1/4 miles to 8+ miles. The output visibility is called sensor prevailing visibility (PV) and is assumed to be that horizontal visibility near the earth's surface representative of visibility conditions in the vicinity of the point of measurement.

1.1 Resolution

Visibility sensors shall determine visibility from "less than 1/4 mile" up to a range of 8+ miles. Visibility of less than 1/4 mile is reported as 0 visibility while visibility greater than 7.5 miles is reported as 8+ miles.

1.2 Significant Changes in Visibility

The system shall provide for determining and reporting when prevailing visibility (rounded to reportable values), decreases to less than, or if below, increases to equal or exceed:

1. 3 miles.
2. 2 miles.
3. 1 1/2 miles.
4. 1 mile.
5. All nationally published minima, applicable to the airport, listed in the National Ocean Survey instrument approach procedure charts or DOD flips.
6. Values established locally because of their significance to local aircraft operations.
7. Up to a total of three additional values will be allowed for conditions 5 and/or6.

1.3 Number of Sensors

One sensor is used in the determination of prevailing visibility. Location of this sensor will be determined by a site survey. A day/night sense

switch is also required. This sense switch is used to determine whether the extinction coefficient is to be translated to a day or night visibility curve.

1.4 Visibility Algorithm

The visibility algorithm shall perform the following functions each minute:

*c Data Collection

a) Get one value of extinction coefficient from the sensor. Sensor data may be preprocessed if necessary to comply with hardware specifications (Appendix I).

b) A check shall be made to determine if a reading is outside sensor limits. If so, the value is bad and the previous good value shall be inserted for up to two consecutive times. The third consecutive time use of the bad sensor shall be discontinued and suitable notification made.

c) Check to see if the day or night sense switch should be set.

*c Convert to Sensor Equivalent Visibility (SEV)

d) Convert each one minute value of extinction coefficient directly to SEV in miles using separate conversion equations (as given in Appendix II) for day and nighttime conditions. (The day/night sense switch shall be read each minute). If SEV is less than 0.25 miles, store 0.0 for the value. If SEV is more than 7.5 miles, store 8.0 for the value.

*c Data Storage

e) Store up to 10 minutes of values from the sensor; i.e., 10 values of SEV.

f) If less than 10 values are stores from the sensor, a visibility estimated message shall be generated.

g) After 10 values have been collected from the sensor, the new value received shall replace the oldest value stored.

*c Sensor Averaging

h) The collected values obtained from Section f or g above shall be linearly averaged and rounded to the nearest reportable value as given below. (Where 8+ is any value greater than 7.5).

*c Reportable Visibility Values

i) Any visibility must be reported in the following values (statute miles):

*c Indicates comments.

0, 1/4, 5/16, 3/8, 1/2, [illegible] 4 7/8, 1, 1 1/8, 1 1/4, 1 3/8, 1 1/2, 1 5/8, 1 3/4, [illegible] 7/8, 2, 2 1/4, 2 1/2, 2 3/4 3, 4, 5, 6, 7 and 8+.

*c Report of PV

j) The values from Section h when converted to a reportable value, as given in i above, shall be considered the updated or current PV unless modified by k below.

*c Reporting Low Visibilities

k) If the reportable value of PV as obtained from Section j is 3 miles or less, use the following procedure: If the updated PV from Section j has not changed by at least two reportable values from the previously reported PV, continue to use the previous PV as the current PV for use in any output message.

*c Variability Check

l) If the value of PV as given in Section j or k above is less than 3 miles, a variability check shall be made using the following criteria:

1. Get the last 10 minutes worth of SEV values from Section d above.

2. Compare each value with its preceeding SEV.

3. If $\left| SEV_i - SEV_{i-1} \right|$ is greater than 0.5 miles, increment a counter.

4. When using all ten comparisons, if the counter is equal to or greater than three; report visibility as variable.

5. Output a remark that the visibility is variable followed by the maximum and minimum SEV values generated in the last 10 minutes and rounded to the nearest reportable value. The remark must be of the following form:

VSBY Min Value v Max Value

Example: VSBY 1/4V1

*c Output Message

m) The current PV will be reported in the visibility section of the Service "A" message or any other display.

*c Indicates comments.

n) Remarks, as generated, will be placed at the end of the Service "A" message or any other display.

*c Special Message Requirements

o) A check shall be made to determine if a special message is required by using the following criteria:

If the current PV obtained from Section j or k (when compared to the last Service "A" visibility) meets any of the criteria listed in Section 1.2, a special Service "A" message must be generated.

*c Update Frequency

p) A new visibility observation shall be generated each minute.

*c Indicates comments.

APPENDIX C

ALWOS SIX-MONTH TEST PLAN FOR DULLES AIRPORT

Last Revision: 11/10/80

Department of Transportation

Federal Aviation Administration

Automated Low-Cost Weather Observation System Test Plan

4.0 Test Data Collection

4.1 ALWOS Data Recorder (Cassette)

4.2 NWS (Silver Spring, MD) Data Storage

4.3 Survey (Opinion) Sheet

4.4 WSO, SAs, and SPs

4.5 Recording Times

4.6 Preventive Maintenance

5.0 Data Analysis

5.1 Comparison Criteria

5.2 Controller Questionnaire Evaluation

5.3 Final Report

5.4 Listing of Computer Algorithms

Appendix A Visibility Algorithm

Appendix B Ceiling Algorithm

1.0 PURPOSE

The purpose of this test is to evaluate the performance of the Automated Low-Cost Weather Observation System (ALWOS) developed by the NWS for the FAA. The tests are designed to evaluate the overall system performance as well as that of the sensors, field electronics, processors, voice unit displays, and any other system component deemed important to system operation. The results of the six (6) month ALWOS evaluation will be summarized in a final report.

2.0 SYSTEM DESCRIPTION

The ALWOS system is shown in a simplified block diagram form in Figure 1. It consists of a complement of weather sensors, interface electronics, processors, display and keyboard. The processed data is also output in audio form using a voice synthesizer operating under microprocessor control. The speech is composed from a vocabulary stored in the processing memory.

The system also provides a communications output which can be utilized at a remote site to log the data and note system status.

2.1 Sensors: Characteristics and Related Processing

Described below are the types of sensors, sensor outputs, accuracy of data, scaling of data on the interface card, the processing of data obtained from the interface card, quality control procedures, and output processing. Before installation, all sensors will be calibrated. They will be checked periodically for accuracy in accordance with National Weather Service routines. (A synchronous motor shall be used to calibrate and check the anemometer; a sling psychrometer for temperature and dew point).

2.1.1 Visibility Meter

Type: EG&G Model 207 Forward Scatter Meter

Type of Input to Interface Card: Analog voltage proportional to the positive and negative log of extinction coefficient, (0-5v)

Accuracy of Data:
- Plus or minus 0.25 miles at one mile
- Plus or minus 0.5 miles at three miles
- Plus or minus 1.25 miles at five miles
- Plus or minus 3.2 miles at eight miles

Processing Applied to Data on Interface Card:
- Convert analog to digital output

ALWOS

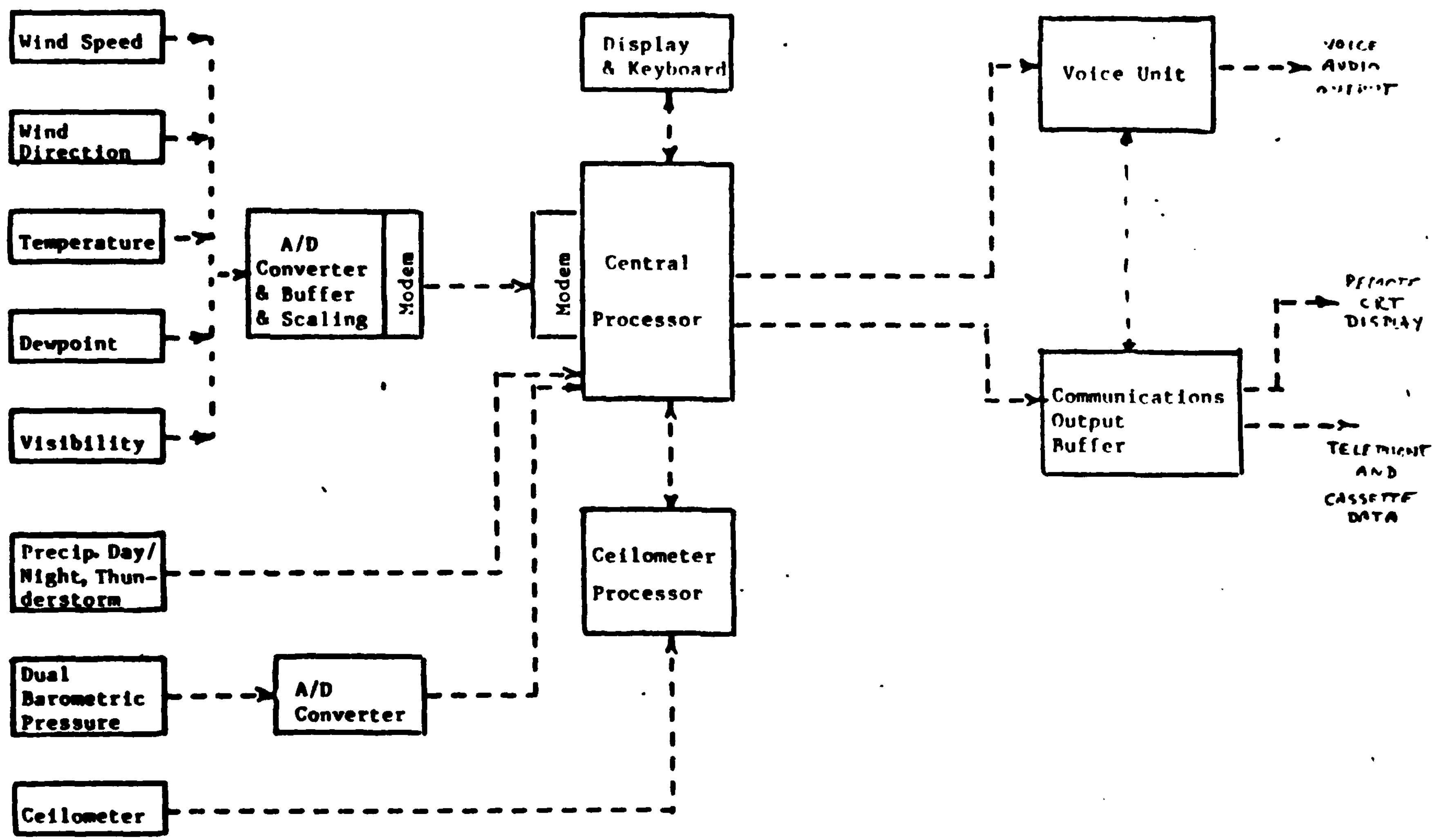


FIGURE 1. SIMPLIFIED BLOCK DIAGRAM

Processing Applied to Data from Interface Card:

The digital values are proportional to the log of the Extinction Coefficient and are sampled once per 10 seconds, converted into sensor equivalent visibility values and formed into a 10-minute running average.

The Day/Night formulas for converting Extinction coefficients to visibilities is $V\sigma = 2.90$ (day) and $.00336V = e^{-\sigma V}$ (night) where V = visibility in miles and σ = extinction Coefficient in miles.$^{-1}$

The output values actually provided, once per minute, are:

0, 1/4, 5/16, 3/8, 1/2, 5/8, 3/4, 7/8, 1, 1 1/8, 1 1/4, 1 3/8, 1 1/2, 1 5/8, 1 3/4, 1 7/8, 2, 2 1/4, 2 1/2, 2 3/4, 3, 4, 5, 6, 7, or 8+ miles. The Model 207-LC Laboratory Calibrator will be used frequently to verify the calibration of the visibility meter.

?.1.2 Wind Speed Sensor

(Cup Driven Tachometer)

Type of Input to Interface Card:

Continuously varying analog voltage (0-5v), 10mv/kt.

Accuracy of Above Data:

Plus or minus 2 knots or 5 percent (whichever is greater)

Processing Applied to Data on Interface Card:

The analog voltage is converted to digital output once every second (eight bits)

Processing Applied to Data from Interface Card:

The central processor receives the eight bits of digital data once every second and averages 60 1-second values for a 1-minute arithmetic average. This average is then scaled and converted to knots. This data is then placed in the output buffer.

Quality Control Applied:

Every second each data is checked against a maximum and minimum value before it is processed into the averaging part of the program. If either maximum or minimum values are exceeded, then a missing character is placed into the output buffer.

Optional Output Criteria:

1) Peak winds, gusts: During every minute, every 1-second value is examined for the peak value. This 1-minute peak value is then stored in a push down store for the last 10-minute values. This

last 10-minute storage is examined once every minute to determine the highest value. If this value is equal to or greater than 14 knots and is greater than or equal to the present 1-minute average plus 5 knots, then this value is used to represent the last 10-minute peak gust wind speed. If this value does not exceed the previous conditions, then two zeros are placed into the output buffer.

2) Calm: If the 1-minute running average wind speed is 2 knots or less, then whatever is in the output buffer for wind speed and direction is replaced by zeros and the voice output reports the winds as "calm".

Tests Applied:
In every message frame a test signal is applied to the interface card to check the calibration of the converter. If it does not verify then a missing indication is placed into the output buffer, and the processor keeps on trying to verify.

2.1.3 Wind Direction Sensor

(Vane Driven Potentiometer With Three Taps)

Type of Input to Interface Card:
Continuously varying analog voltage buffered by operational amplifiers

Accuracy of Sensor:
Ten degrees RMS (0-360 degrees)

Processing Applied to Data from Interface Card:
The central processor receives the eight bits of digital data once every second and averages this data exponentially to an equivalent of a 1-minute running average. This average is then scaled and converted to an output representing wind direction to the nearest 10 degrees of magnetic north for the voice output and true north for the displays. When the wind direction is from the north, 360 is used rather than zero as the wind direction. When the wind speed is 2 knots or less, 00/00 represents the wind direction and speed on the display and "calm" is reported on the voice output.

Data Quality Control Applied:

Tests Applied:

A test signal is applied to the interface card to check the calibration of the converter. If it does not verify, then a missing indication is placed into the output buffer. Upon any missing condition, the processor applies the checks again and if the output verifies, it continues normal operation. If not, it will try again every second.

2.1.4 Temperature and Dew Point Sensors

Temperature-YSI Triple Element Thermistor.
Dew Point-Same Thermistor enclosed within a dewcell bobbin.
Both sensors mounted in Gill aspirated radiation shelters.

Type of Input Into Card:

Continuously varying resistance converted to analog voltage signals buffered by operational amplifier, 10mv/^{o}F.

Processing Applied to Input on The Interface Card:

Data is converted once every 10 seconds to digital data.
The Temperature Algorithm is E_{out}=-0.00310638 x E_{in} x T+.6924E_{in}, E_{in}=3.219.
The Dew Point Algorithm is E_{out}=-.00416011 x E_{in} x T+.597435E_{in}, E_{in}=2.404.

Processing Applied to Data from Interface Card:

The central processor uses 6 of the 10-second samples to form the 1-minute average temperature and dew point every minute. This data is then pushed into a running 5-minute storage. Every minute the 5-minute average is determined and converted to Fahrenheit.

Quality Control Applied:

Every new 1-minute sample of the input data is compared to the previous 1-minute average and, if it varies by more than plus or minus six (6) degrees Fahrenheit, a "missing" is placed into the output. Once every message frame a test reference voltage is applied to the interface and if it does not verify, a "missing" is also placed into the output.

Tests Applied:
Dew point data is not considered valid unless its value is less than or equal to the temperature value.

2.1.5 Impulsphysik Ceilometer

Type: Pulsed GaAs Laser

Range: 100 to 3,000 feet

Type of Input to Interface Card:
An EIA RS-232 voltage loop, serial digit format, 110 baud, asynchronous, 1 start-2 stop and 8 bits of data. The asynchronous data stream is issued once per 28 seconds headed by an STX character and ended with an ETX character. In between are 63 bytes, representing returns from 50-foot range bins from 100 feet to 3,100 feet. The returns are binary encoded from 00 to FF representing the backscattered energy received in that range bin.

Processing Applied to Input:
A dedicated processor card will input the data, determine cloud strikes and heights, then process the data in accordance with Autob (automatic observer) algorithm rules. Cloud layer levels and sky condition (broken, scattered or overcast) are determined and presented in the output. One hundred-foot levels are given. The data is a 23-minute running average produced each 4 minutes. The Autob algorithm uses visibility data as an input. Quality checks are available on receiver sensitivity and laser power.

2.1.6 Pressure Sensors (Garrett AiResearch No. 2101800 Quartz, Capacitive-Plate)

Type of Input to Interface Card:
Continuously varying analog voltage 0.3387 v/in Hg, 0v = 17.718"Hg, 4.6v = 31.3" Hg

Accuracy of Above Data:
Plus or minus 0.15% of range.
Worst case from 60 KPA to 100 KPA where (.07 KPA = 0.7 MB = 0.02")

Processing Applied to Data on Interface Card:
Converts analog voltage once every 10 seconds to digital output (12 bits).
Elevation constants for altimeter processing are stored in a programmable read only memory (PROM). Offset or calibration voltages for both sensors are adjusted on the local input card and read into the local A/D converter to correct the pressure readings. These values are read by the processor.

Processing Applied to Data from Interface Card:
Dual pressure sensors, contained in an oven and thermostatically controlled supply input data. The input data are used to form two 1-minute averages of "inches of mercury". If they vary by more than 0.04", then a "missing" is placed into the output buffer. If the difference is less than or equal to 0.04" Hg then the lower value of the two is used to calculate altimeter setting.

Start Up Conditions:
Data is not considered valid until a 25-minute warm-up period has taken place. The pressure data can be displayed immediately by operation of an override key.

Calibration:
A recording barograph installed in close proximity to the pressure sensors will continuously monitor the ASI readings. Also, the accuracy of the ASI output will be checked biweekly using a Wallace and Tiernan portable transfer standard.

2.1.7 Thunderstorm Sensors

Type: Broad band antenna, detection of base of return stroke.

Manufacturer:
Atlantic Scientific

Type of Input to Interface Card:
Contact Closure - 0v = no thunderstorms
5v = thunderstorms

Processing Applied to Data from Interface Card:
One-second sampling of thunderstorm sensor output

2.2 Remoting Field Data

Most of the sensors are located near the center of the airport and data obtained from them must be digitized and transmitted serially to an equipment room where the data is processed by a central processor which in the ALWOS system is the Intel 80/20 microcomputer.

Analog information from sensors representing wind speed, wind direction, temperature, dewpoint and visibility enter a centerfield located enclosure where the information is converted into digital form. Within the enclosure are multiplexers, A/D converters send-modems, a heater, blower, lightning arresting devices, power supplies shut-down and turn-on electronics. A completely dual data handling system is provided.

The ALWOS system in its field unit has the following data in 16 analog channels:

Channel	Data
0	Temperature
1	Dew Point
2	Visibility (Pos. Logarithmic)
3	Visibility (Neg Logarithmic)
4	Wind Speed
5	Wind Direction A
6	Wind Direction B
7	Wind Direction C
8	+5.0V DC Reference to Wind Direction Sensor
9	+3.219V DC Reference to Temperature Thermistor
10	+2.404V DC Reference to Dew Point Thermistor
11	+2.5V DC Divided down from the +20V power supply
12	+2.5 V DC Divided down from the +5V power supply
13	+1.0V DC Divided down from the ±15V power supplies
14	Heater On Indication (Yes=+5V)
15	0V DC Ground Reference

This data in each channel is represented in 12-bit form and identified by four address bits. Sixteen additional channels and an additional identifier bit are available but not used in the present configuration.

The electronics in the field unit are self synchronized (each channel) and provide data serially to a Line Switch Modulator Modem which supplies data at approximately 2720 bits per second over a landline that carries the data to the ALWOS central processor in the designated equipment room, ~~at the Dulles Control Tower~~. The data is demodulated by a Line Switch Demodulator before entering the central processor.

2.3 LED Incoming Data Display

The incoming data from the field unit is displayed on a row of LED lights on the ALWOS console. Seventeen bits are shown, twelve for data, five for identification of type of data.

2.4 Central Processor

The central processor accepts the demodulated data from the field ~~emit~~ unit, from the Precipitation, Thunderstorm, Day-Night and Decal Barometric Pressure Sensors. The central processor also accepts data from the ceilometer processor (A separate Intel 80/20 microcomputer). The Central Processor is an 8-bit microprocessor which performs all averaging, detects out-of-limit data and data rates, and formats all output data from the voice unit, CRT display and communications output.

2.5 Voice Unit

The voice unit, a format, synthesizer and a prestored vocabulary (PROM) of formant encoded words is provided on a card which is manufactured by Speech Technology Inc. of California.

The voice unit is a printed circuit board which plugs into the subrack with the CP. It accepts data from the Central Processor. It is directed to say "data is missing" wherever any sensor has out-of-limit values or excessive rates of change in values.

2.6 CRT Display

A CRT accepts data from the central processor displays output data once per minute. Since this display also prints the display of raw data it is a useful maintenance/installation tool. It can also be used to demonstrate the operation of the system to controllers and/or other evaluator.

2.7 Communication

The system outputs to users the derived weather products and the system status using a low-rate (300 baud) RS232 communication link. This allows remote display and recording of the weather data and initiation of corrective maintenance if required.

2.1.8 Precipitation Yes/No Sensor

Type: Resistance grid.

Manufacturer:
Wong Labs.

Type of Input to Interface Card:
0v = no precipitation
+5v = precipitation

Processing Applied to Data from Interface Card:
A 1-minute sampling of the Precipitation Y/N Sensor Output is performed.

2.1.9 Day/Night

Manufacturer:
Precision Multiple Controls, Inc.

Type of Input to Interface Card:
0v = night
+5v = day

This data is supplied to the visibility routine where either the day formula $V\sigma = 2.90$ or the night formula $.00336V = e^{-\sigma V}$ are used.

3.0 SYSTEM INSTALLATION AND CHECKOUT

3.1 Installation

The system will be installed at the Dulles International Airport. The sensors, consisting of Wind Speed and Direction, Temperature, Dew Point, Thunderstorm, Visibility, Ceiling, and the field electronics are centrally located on the airport in close proximity to the Rotating Beam Ceilometer (RBC) and the operational transmissometer. The dual pressure transducers, day/night, and precipitation sensors will be located at the NWS building adjacent to the FAA control tower. The ALWOS electronics, consisting of the processors, displays, etc., are located inside the NWS building. A remote CRT and speaker with on/off switch will be installed in the Dulles Tower complex for the purpose of permitting controllers and maintenance personnel to monitor and observe the system output. The system will not be used operationally.

Evaluation of the ALWOS system performance will require the use of data, taken from an independent set of sensors, provided by the NWS Weather Service Office (WSO) which is located near the ALWOS site. The WSO equipment consists of temperature, dew point, pressure sensors,

and Rotating Beam Ceilometer. When the NWS observer visibility is 1 mile or below, obtain transmissometer trace for runway ____. Transmissometer data converted to visibility (as RVV) will be compared with observer and EG&G visibility data.

The official NWS weather data as given on the daily summary sheet of SAs and SPs will be used as the standard for comparison with the ALWOS system output data.

An ALWOS remote display and speaker will be located in a room in the Dulles Control Tower building for viewing and listening by controllers and other personnel participating in the system evaluation.

3.2 Checkout

Following the installation of the ALWOS system, the equipment shall be tested using a simulated set of sensor inputs. Where analog inputs are simulated, the voltage source shall be capable of supplying 0-5v to a resolution of ± 1 mv. A digital voltmeter shall be used to check the accuracy of the voltage settings. Digital inputs shall be simulated using a microprocessor, or a similar digital device.

Based on the known simulated inputs applied to ALWOS processors, the processed output shall agree with the input to the following tolerances:

Wind Speed	To nearest 2 Kts
Wind Direction	To nearest 10°
Wind Gusts	To nearest 2 Kts
Temperature	To nearest 1°F
Dew Point	To nearest 1°F
Altimeter Setting	To nearest 0.02"Hg
Visibility	To nearest 1/16 of a mile or more depending on range
Ceiling	To nearest 100 Ft.

The simulated inputs shall also be used to check the system failure detection, algorithms, display and voice outputs, and the recordings of the output products.

4.0 TEST DATA COLLECTION

Test Data will be collected at Dulles International Airport during the 6-month demonstration period.

4.1 ALWOS Data Recorder (Cassette)

The processed sensor data are recorded on a Techtran Cassette Recorder once every 20 minutes. The data are presented serially, in ASCII format, at 300 baud and RS-232 levels. A Status (or Maintenance) word is also recorded. The Maintenance word bits and types of failures are shown below.

Bit	Type of Failed Device
0	Temperature
1	Dew Point
2	Wind Speed
3	Wind Direction
4	Pressure #1
5	Pressure #2
6	Pressure Calibration (a voltage check)
7	Visibility
8	Internal A/D (Intel SBC 711)
9	Remote A/D #1
10	Remote A/D #2
11	Unused
12	Unused
13	Unused
14	Unused
15	Unused

The bits are encoded as numbers from 0 to 2047.

Also recorded are ASCII symbols for carriage return, line feed, etc., so that the tape recorder output may be fed into a Silent 700 Printer and formatted into a clearly understandable printed page of data. Approximately 50 bytes make up a message frame.

4.2 NWS (Silver Spring) Data Storage

A telephone line from Dulles International Airport will be used to remote data to the NWS Equipment Development Laboratory. The data may be archived on a disk, and/or displayed on a CRT display, or printed. The data transfer rate will be 300 baud.

4.3 Opinion Sheet

An opinion sheet will be distributed for obtaining impressions from controllers and other subjects who will be asked to evaluate the ALWOS system. The questions will be directed toward evaluating the intelligibility of vocal and displayed messages.

A sample Opinion Sheet is shown below.

SURVEY (OPINION) SHEET

DULLES AUTOMATED LOW-COST WEATHER OBSERVATION SYSTEM (ALWOS)

1. VOICE QUALITY: YES NO

   a. Did you bave difficulty understanding a particular word or phrase? ___ ___

   b. If yes to above question, please identify:

   ____

   ____

2. WHAT IS YOUR OVERALL OPINION OF THE ALWOS VOICE?

   ____

   ____

   ____

3. WHAT DO YOU THINK OF THE ALWOS CONCEPT?

   ____

   ____

   ____

4. ANY SUGGESTIONS FOR CHANGES OR IMPROVEMENT?

   ____

   ____

   ____

5. PLEASE LIST YOUR SPECIALTY:

   a. AAT ________

   b. AAF ________

   c. OTHER ________

Thank you for your help. If you have any questions, or if you would like more information on the system, please write or call:

David Floyd or John Dorman - Washington Headquarters:
(202)426-8427

Federal Aviation Administration
ARD-412
400 - 7th Street, SW
Washington, DC 20590

4.4 WSO SAs and SPs

The daily summaries of hourly surface observations, SAs, or Specials, SPs, taken at the Dulles Weather Service Office (WSO) will be collected and used as standards for comparison with the output of the ALWOS system.

The values to be obtained from the official NWS SAs and SPs are time, sky, ceiling, visibility, temperature, dew point, wind speed and direction, gust, and altimeter setting.

4.5 Recording Times

The ALWOS Data Recorder will record approximately 50 bytes of data every 20 minutes.

Remote recording at the NWS Equipment Development Laboratory may also be performed at the same rate.

4.6 Preventive Maintenance

To discover trends in the operation of the ALWOS and its sensors in a timely manner, a qualified weather observer or technician shall visit the site every Monday, Wednesday, and Friday, and shall have available readings for the last period. He shall compare the last readings obtained by ALWOS to those obtained by the NWS observer at the WSO. If he discovers that the system output data, in whole or in part, does not agree with the official weather, he should perform, or cause to be performed, one or all of the following tests as needed:

1. Run diagnostics on the computer (if available).
2. Simulate inputs and observe outputs.
3. Check individual outputs of sensors.
4. Use checkout procedures and tolerances shown in Section 3.2.

5.0 DATA ANALYSIS

5.1 Comparison Criteria

The SAs and SPs will be compared with the output of the ALWOS system. Since the sensors differ in their locations they can be expected to show

different results. The following list of parameters and their tolerances shall be used as a basis for comparison. The comparison will be done every other day (Monday, Wednesday, Friday). Any discrepancies between the observations will be noted in a log book which will be kept at the ALWOS location.

The list of parameters or comparison is an initial list to be used for early comparisons. The values given show an attempt to take into consideration the distance factor between the two sets of sensors. After a few weeks of testing and observation of phenomena due to siting, the comparison parameters may have to be tightened or opened in some of the readings.

COMPARISON OF ALWOS AND NWS DATA

TOLERANCES

Wind Direction	$\pm$ 30° 5 to 20 KTS $\mp$ 20° 20 KTS & up
Wind Speed	$\pm$ 5 KTS
Temperature	$\pm$ 3° F
Dew Point	$\pm$ 5° F
Visibility	1/4 mile 1/4 - 3 miles 1 mile 3-8 miles
Ceiling Height & Sky Condition	500 Ft. and exact descriptor
Altimeter	.04" Hg
Precipitation Thunderstorm	Exact descriptor

5.2 Controller Questionnaire Evaluation

The intelligibility of the ALWOS messages will be resolved from the questionnaire. The voice quality will be also determined from their responses.

Only a rough measure of voice quality and intelligibility will be obtained by querying the controllers. The Voice Unit can be tested in a stand alone test with standard tests such as Diagnostic Rhyme Tests, which are designed to obtain measures of intelligibility and voice quality. Usually, the manufacturer of the Voice Unit has previous records of such tests. These should be obtained from the manufacturer or from Federal Agencies such as the Air Force Electronics Systems Division who make these tests, if possible.

Since the ALWOS vocabulary does not contain the standard word test set, the quality of the ALWOS speech will be evaluated based on recognition of the message and any specific words which apply to the standard test set.

5.3 Final Report

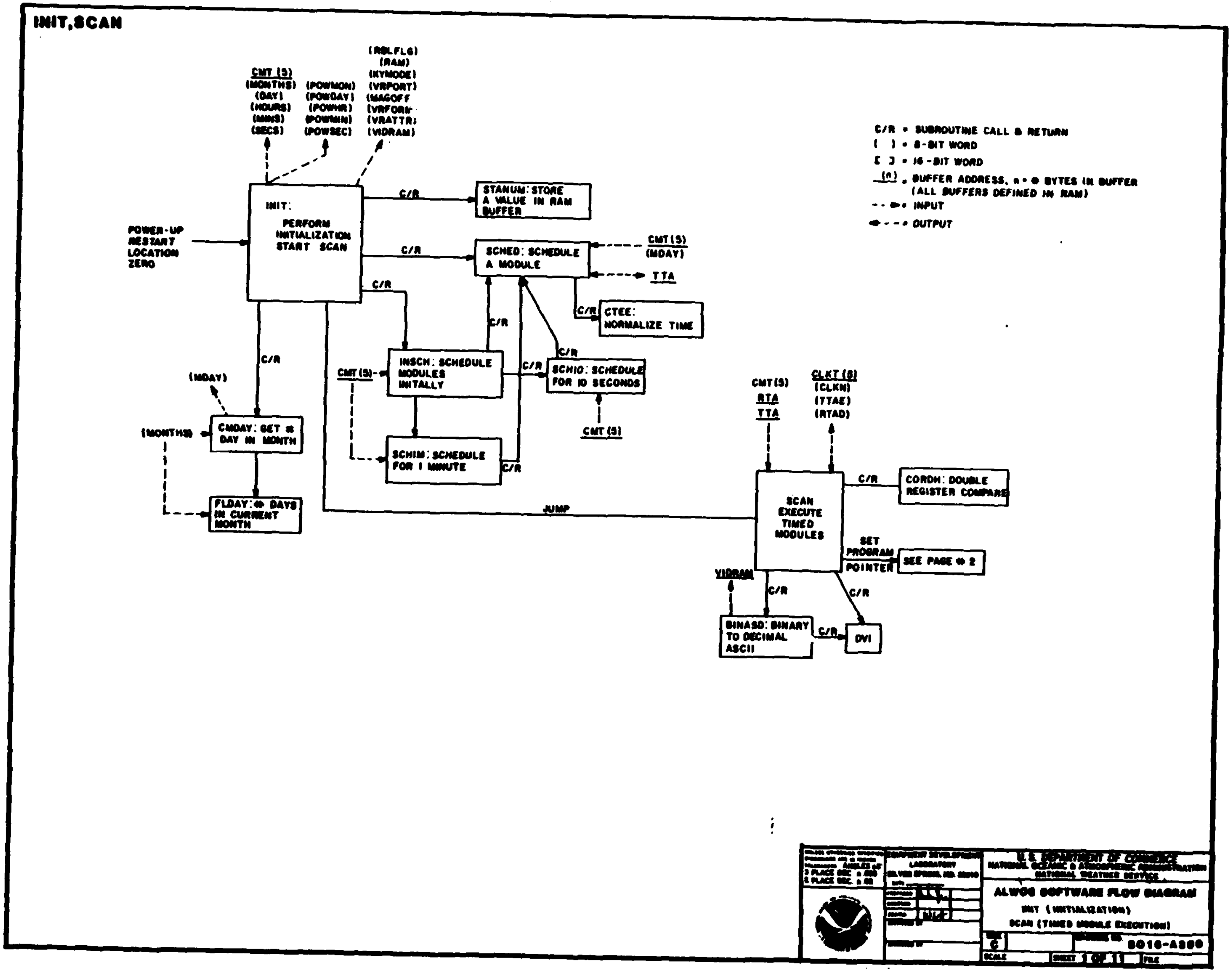
A final report will be written which will analyze all of the instances where the ALWOS system outputs varied excessively, i.e., beyond the tolerances given in Section 5.1. Statistics will be provided, giving the frequency that a particular weather parameter was "out of tolerance." Explanations will be offered for those "out of tolerance" cases when they can be found. For example, the time that hourly surface observations are made vary by several minutes, from hour to hour. Thus, the ALWOS data may be for times several minutes removed from the hourly surface observations.

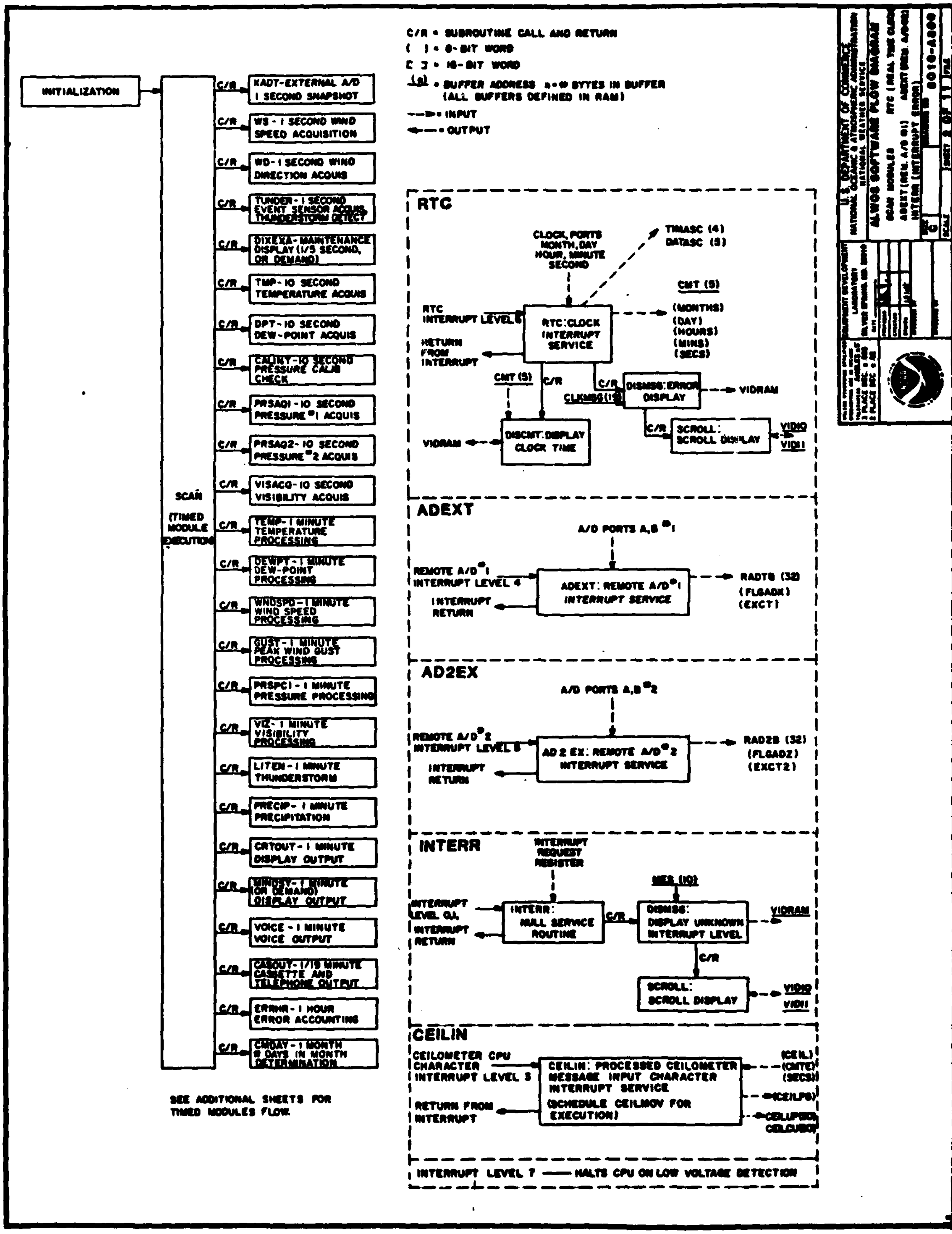
In addition, the report shall list all ALWOS sensor or equipment failures when they occurred, under what conditions, and what was the probable cause. The hourly surface observations and the ALWOS printouts during the period of evaluation will be preserved as an appendix to the final report.

5.4 Listing of Computer Algorithms

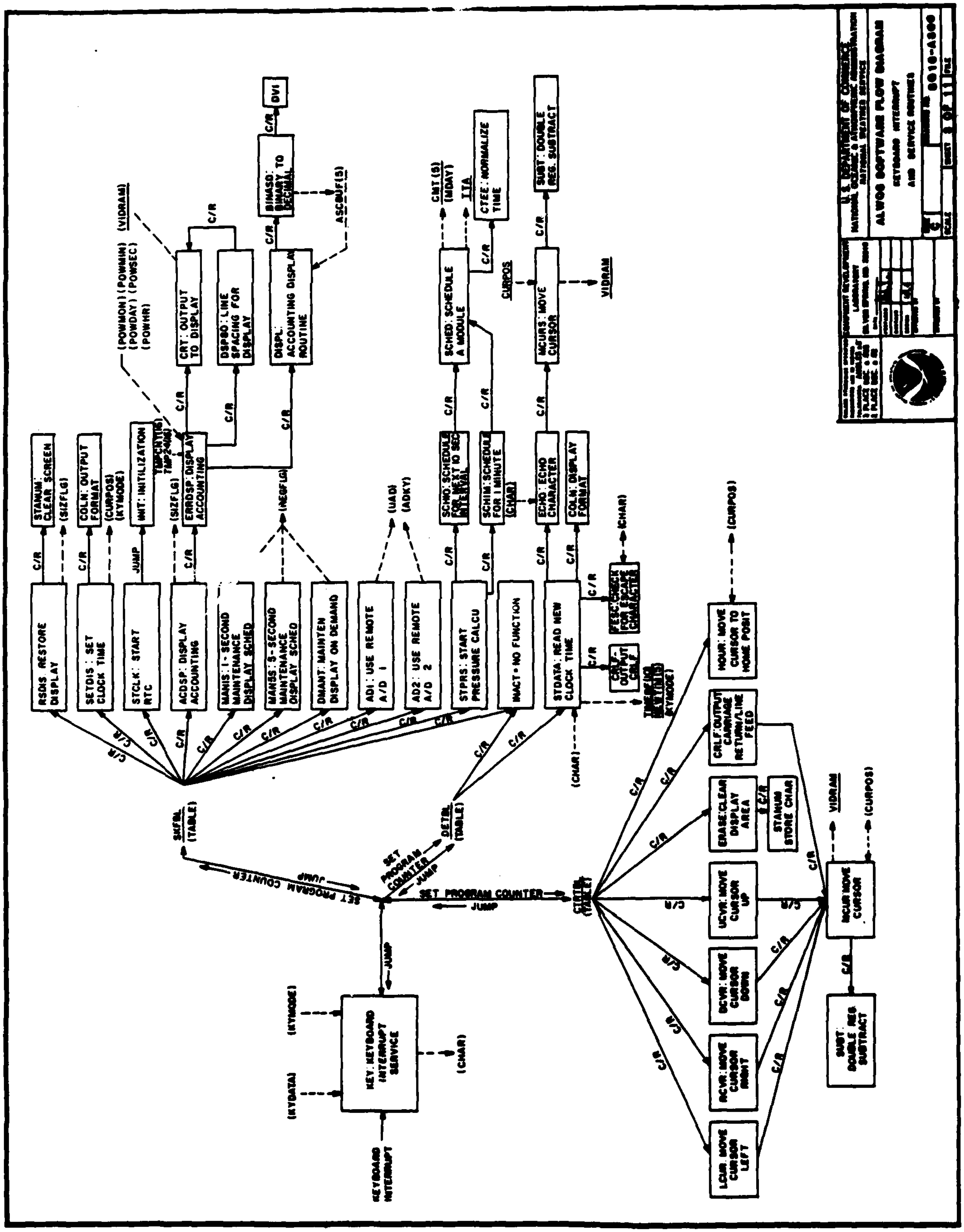
APPENDIX D

SOFTWARE INTER-MODULE COMMUNICATIONS FLOW DIAGRAMS

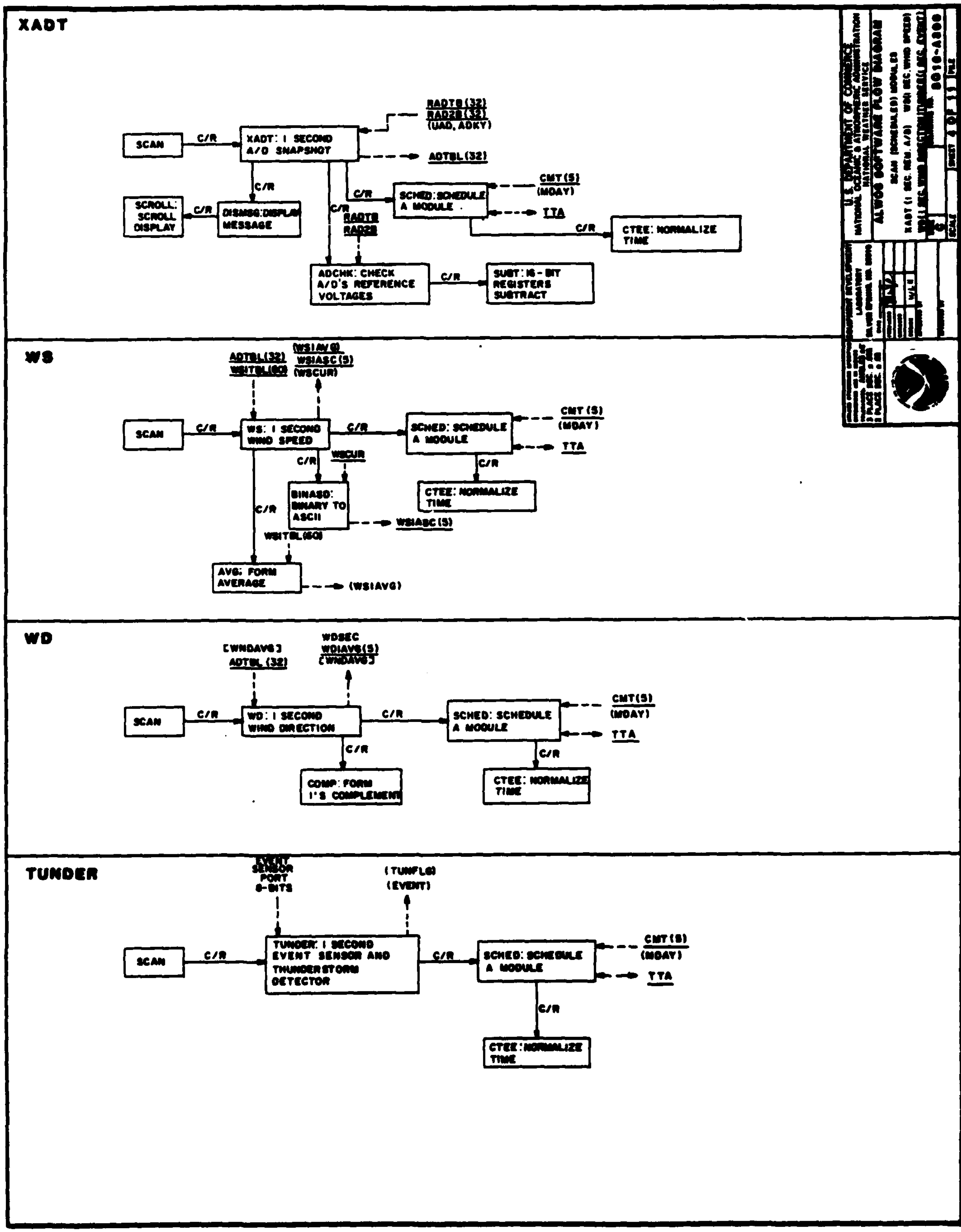

INIT,SCAN
CMT (5)
(MONTHS)
(DAY)
(HOURS)
(MINS)
(SECS)
(POWMON)
(POWDAY)
(POWHR)
(POWMIN)
(POWSEC)
(RBLFLG)
(RAM)
(KYMODE)
(VRPORT)
(MAGOFF
(VRFORM
(VRATTR)
(VIDRAM)
C/R = SUBROUTINE CALL & RETURN
( ) = 8-BIT WORD
[ ] = 16-BIT WORD
(n) = BUFFER ADDRESS, n = # BYTES IN BUFFER (ALL BUFFERS DEFINED IN RAM)
INPUT
OUTPUT
POWER-UP RESTART LOCATION ZERO
INIT: PERFORM INITIALIZATION START SCAN
C/R
STANUM: STORE A VALUE IN RAM BUFFER
SCHED: SCHEDULE A MODULE
CMT (5)
(MDAY)
TTA
CTEE: NORMALIZE TIME
INSCH: SCHEDULE MODULES INITALLY
SCHIO: SCHEDULE FOR 10 SECONDS
SCHIM: SCHEDULE FOR 1 MINUTE
(MDAY)
(MONTHS)
CMDAY: GET # DAY IN MONTH
FLDAY: # DAYS IN CURRENT MONTH
JUMP
CMT (5)
RTA
TTA
CLKT (8)
(CLKN)
(TTAE)
(RTAD)
SCAN EXECUTE TIMED MODULES
CORDH: DOUBLE REGISTER COMPARE
SET PROGRAM POINTER
SEE PAGE # 2
VIDRAM
BINASD: BINARY TO DECIMAL ASCII
DVI
U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC & ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE
COMPONENT DEVELOPMENT LABORATORY
SILVER SPRING, MD. 20910
ALWOS SOFTWARE FLOW DIAGRAM
INIT (INITIALIZATION)
SCAN (TIMED MODULE EXECUTION)
C
8010-A300
SCALE
SHEET 1 OF 1

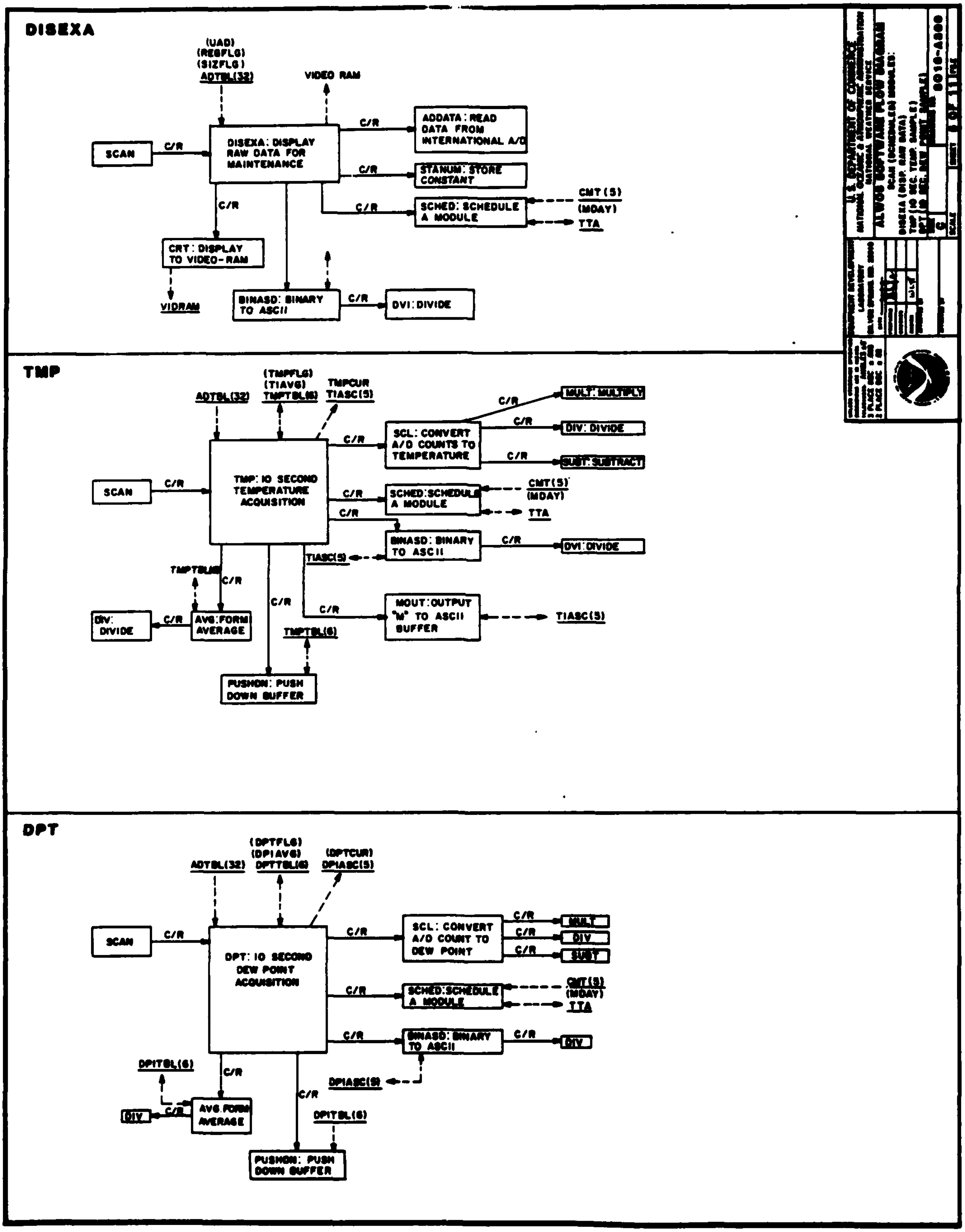


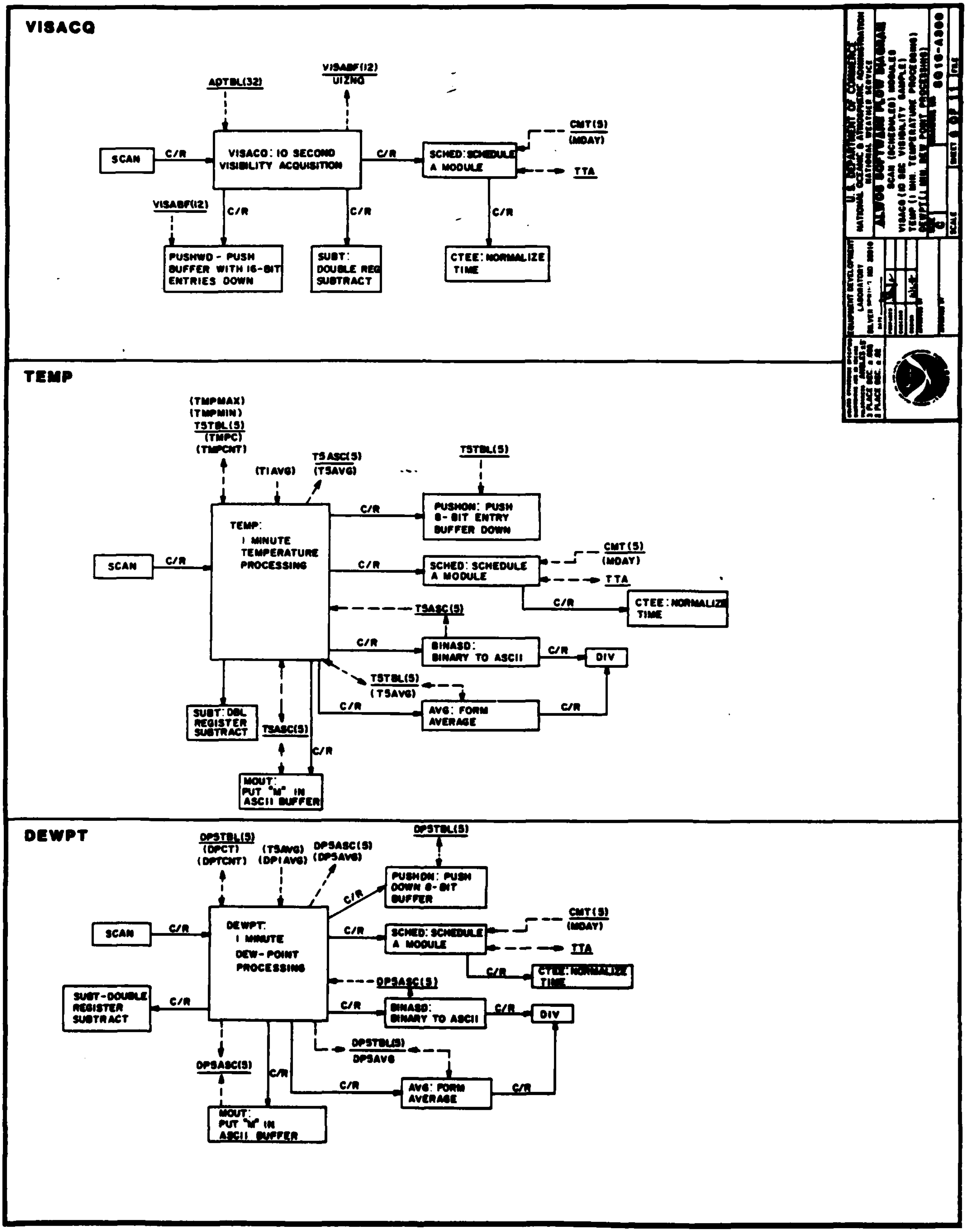
C/R = SUBROUTINE CALL AND RETURN
( ) = 8-BIT WORD
[ ] = 16-BIT WORD
(n) = BUFFER ADDRESS n = # BYTES IN BUFFER (ALL BUFFERS DEFINED IN RAM)
→ = INPUT
← = OUTPUT
INITIALIZATION
SCAN (TIMED MODULE EXECUTION)
C/R
XADT-EXTERNAL A/D 1 SECOND SNAPSHOT
WS - 1 SECOND WIND SPEED ACQUISITION
WD - 1 SECOND WIND DIRECTION ACQUIS
TUNDER - 1 SECOND EVENT SENSOR ACQUIS THUNDERSTORM DETECT
DIXEXA - MAINTENANCE DISPLAY (1/5 SECOND, OR DEMAND)
TMP - 10 SECOND TEMPERATURE ACQUIS
DPT - 10 SECOND DEW-POINT ACQUIS
CALINT - 10 SECOND PRESSURE CALIB CHECK
PRSAQ1 - 10 SECOND PRESSURE #1 ACQUIS
PRSAQ2 - 10 SECOND PRESSURE #2 ACQUIS
VISACQ - 10 SECOND VISIBILITY ACQUIS
TEMP - 1 MINUTE TEMPERATURE PROCESSING
DEWPT - 1 MINUTE DEW-POINT PROCESSING
WNDSPD - 1 MINUTE WIND SPEED PROCESSING
GUST - 1 MINUTE PEAK WIND GUST PROCESSING
PRSPC1 - 1 MINUTE PRESSURE PROCESSING
VIZ - 1 MINUTE VISIBILITY PROCESSING
LITEN - 1 MINUTE THUNDERSTORM
PRECIP - 1 MINUTE PRECIPITATION
CRTOUT - 1 MINUTE DISPLAY OUTPUT
MINOUT - 1 MINUTE (OR DEMAND) DISPLAY OUTPUT
VOICE - 1 MINUTE VOICE OUTPUT
CASOUT - 1/15 MINUTE CASSETTE AND TELEPHONE OUTPUT
ERRHR - 1 HOUR ERROR ACCOUNTING
CMDAY - 1 MONTH # DAYS IN MONTH DETERMINATION
SEE ADDITIONAL SHEETS FOR TIMED MODULES FLOW
RTC
CLOCK, PORTS MONTH, DAY HOUR, MINUTE SECOND
TIMASC (4)
DATASC (5)
CMT (5)
RTC INTERRUPT LEVEL 6
RTC: CLOCK INTERRUPT SERVICE
(MONTHS) (DAY) (HOURS) (MINS) (SECS)
RETURN FROM INTERRUPT
CMT (5)
C/R
DISMSG: ERROR DISPLAY
VIDRAM
CLKMSG (15)
DISCMT: DISPLAY CLOCK TIME
SCROLL: SCROLL DISPLAY
VID10
VID11
ADEXT
A/D PORTS A,B #1
REMOTE A/D #1 INTERRUPT LEVEL 4
ADEXT: REMOTE A/D #1 INTERRUPT SERVICE
RADTB (32) (FLGADX) (EXCT)
INTERRUPT RETURN
AD2EX
A/D PORTS A,B #2
REMOTE A/D #2 INTERRUPT LEVEL 5
AD2EX: REMOTE A/D #2 INTERRUPT SERVICE
RAD2B (32) (FLGADZ) (EXCT2)
INTERRUPT RETURN
INTERR
INTERRUPT REQUEST REGISTER
MES (10)
INTERRUPT LEVEL 0,1,
INTERR: NULL SERVICE ROUTINE
DISMSG: DISPLAY UNKNOWN INTERRUPT LEVEL
VIDRAM
INTERRUPT RETURN
SCROLL: SCROLL DISPLAY
VID10
VID11
CEILIN
CEILOMETER CPU CHARACTER INTERRUPT LEVEL 3
CEILIN: PROCESSED CEILOMETER MESSAGE INPUT CHARACTER INTERRUPT SERVICE (SCHEDULE CEILMOV FOR EXECUTION)
(CEIL) (CMTE) (SECS)
(CEILPS)
CEILUPSO
CEILCUBO
RETURN FROM INTERRUPT
INTERRUPT LEVEL 7 —— HALTS CPU ON LOW VOLTAGE DETECTION
U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC & ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE
ALWOS SOFTWARE FLOW DIAGRAM
SCAN MODULES
RTC (REAL TIME CLOCK)
ADEXT (REM. A/D #1)
AD2EX (REM. A/D #2)
INTERR (INTERRUPT ERROR)
SHEET 2 OF 11

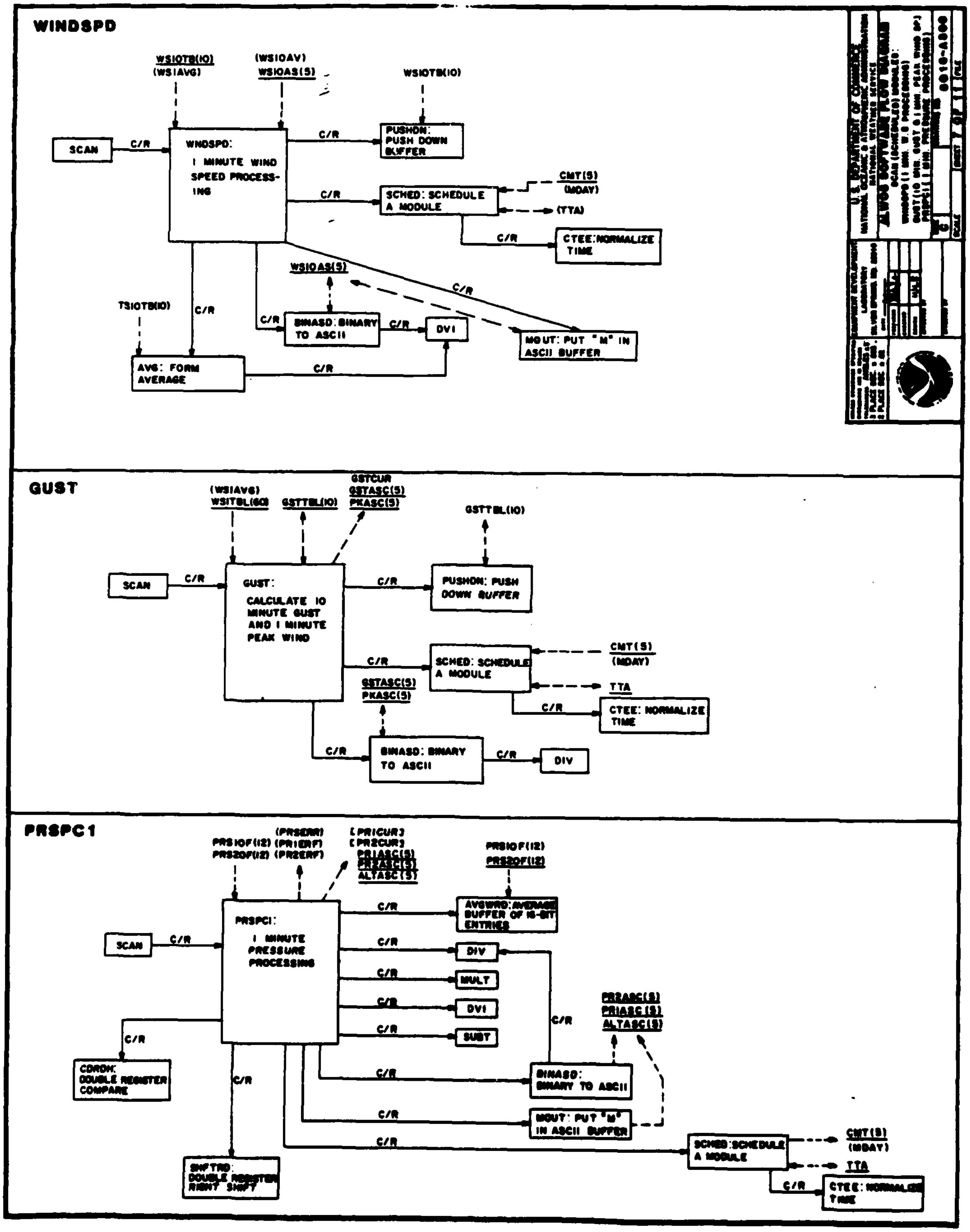


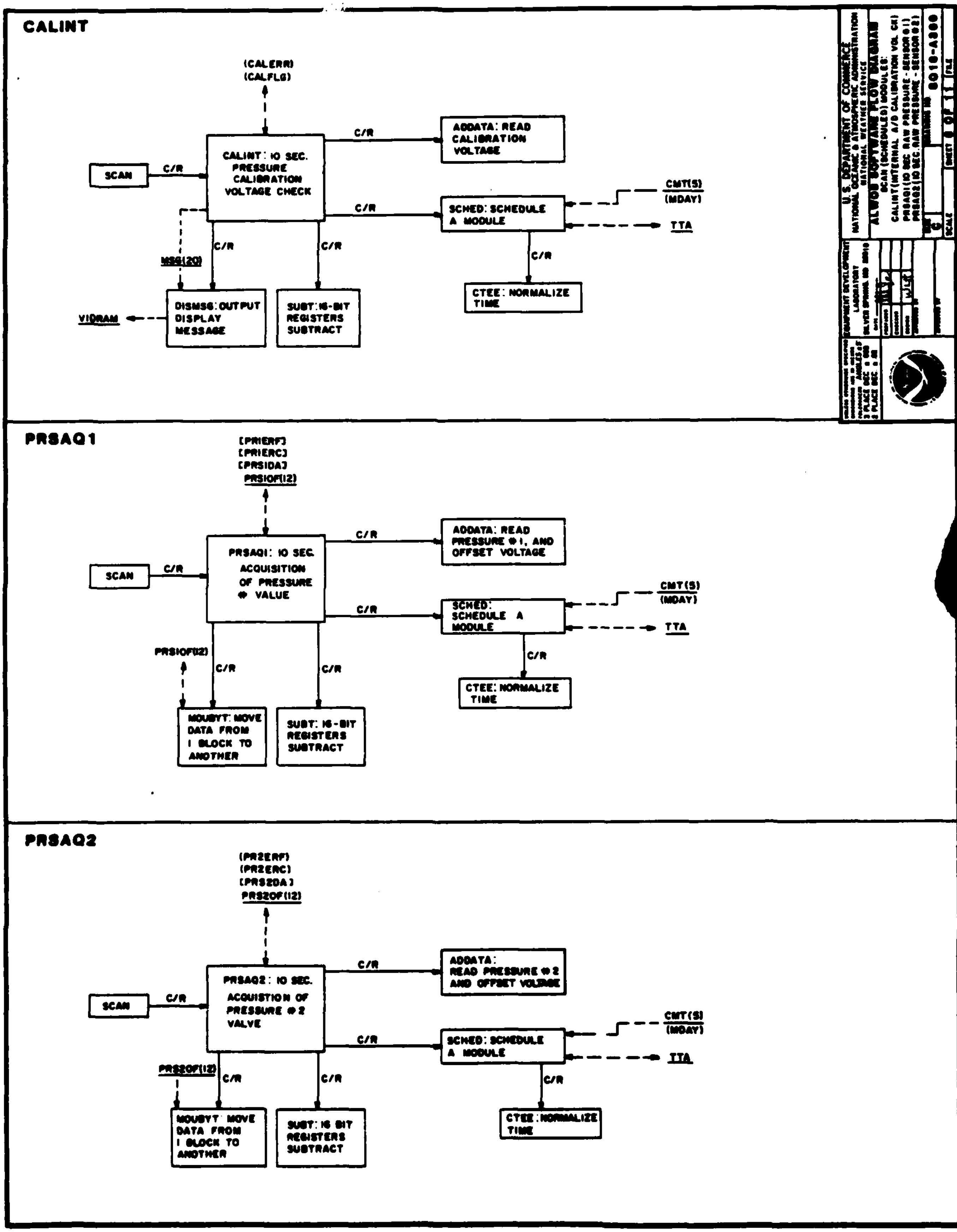
KEYBOARD INTERRUPT
KEY: KEYBOARD INTERRUPT SERVICE
(KYDATA)
(KYMODE)
(CHAR)
JUMP
SET PROGRAM COUNTER
SKFBL (TABLE)
DETBL (TABLE)
RSDIS: RESTORE DISPLAY
SETDIS: SET CLOCK TIME
STCLK: START RTC
ACDSP: DISPLAY ACCOUNTING
MANIS: 1-SECOND MAINTENANCE DISPLAY SCHED
MANSS: 5-SECOND MAINTENANCE DISPLAY SCHED
DMANT: MAINTEN DISPLAY ON DEMAND
AD1: USE REMOTE A/D 1
AD2: USE REMOTE A/D 2
STPRS: START PRESSURE CALCU
NACT: NO FUNCTION
STDATA: READ NEW CLOCK TIME
STANUM: CLEAR SCREEN
COLN: OUTPUT FORMAT
INIT: INITILIZATION
ERRDSP: DISPLAY ACCOUNTING
CRT: OUTPUT TO DISPLAY
DSPSO: LINE SPACING FOR DISPLAY
DISPL: ACCOUNTING DISPLAY ROUTINE
BINASD: BINARY TO DECIMAL
DVI
ASCBUF(S)
(POWMON) (POWMIN) (POWDAY) (POWSEC) (POWHR)
(VIDRAM)
SCHIO: SCHEDULE FOR NEXT 10 SEC INTERVAL
SCHIM: SCHEDULE FOR 1 MINUTE
SCHED: SCHEDULE A MODULE
CTEE: NORMALIZE TIME
ECHO: ECHO CHARACTER
COLN: DISPLAY FORMAT
MCURS: MOVE CURSOR
SUBT: DOUBLE REG. SUBTRACT
CRLF: OUTPUT CRLF
PESC: CHECK FOR ESCAPE CHARACTER
LCUR: MOVE CURSOR LEFT
RCVR: MOVE CURSOR RIGHT
DCVR: MOVE CURSOR DOWN
UCVR: MOVE CURSOR UP
ERASE: CLEAR DISPLAY AREA
STANUM STORE CHAR
CRLF: OUTPUT CARRIAGE RETURN/LINE FEED
HOUR: MOVE CURSOR TO HOME POSIT
NCUR: MOVE CURSOR
SUBT: DOUBLE REG SUBTRACT
VIDRAM
(CURPOS)
C/R
U.S. DEPARTMENT OF COMMERCE
NATIONAL WEATHER SERVICE
ALWOS SOFTWARE FLOW DIAGRAM
KEYBOARD INTERRUPT AND SERVICE ROUTINES


XADT
SCAN
C/R
XADT: 1 SECOND A/D SNAPSHOT
RADTB(32)
RAD2B(32)
(UAD, ADKY)
ADTBL(32)
SCROLL: SCROLL DISPLAY
DISMSG: DISPLAY MESSAGE
SCHED: SCHEDULE A MODULE
CMT(5)
(MDAY)
TTA
CTEE: NORMALIZE TIME
RADTB
RAD2B
ADCHK: CHECK A/D'S REFERENCE VOLTAGES
SUBT: 16-BIT REGISTERS SUBTRACT
WS
ADTBL(32)
WS1TBL(60)
(WS1AVG)
WS1ASC(5)
(WSCUR)
WS: 1 SECOND WIND SPEED
WSCUR
BINASC: BINARY TO ASCII
WS1ASC(5)
WS1TBL(60)
AVG: FORM AVERAGE
(WS1AVG)
WD
[WNDAVG]
ADTBL(32)
WDSEC
WD1AVG(5)
[WNDAVG]
WD: 1 SECOND WIND DIRECTION
COMP: FORM 1'S COMPLEMENT
TUNDER
EVENT SENSOR PORT 8-BITS
(TUNFLG)
(EVENT)
TUNDER: 1 SECOND EVENT SENSOR AND THUNDERSTORM DETECTOR
U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC & ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE
ALWOS SOFTWARE FLOW DIAGRAM

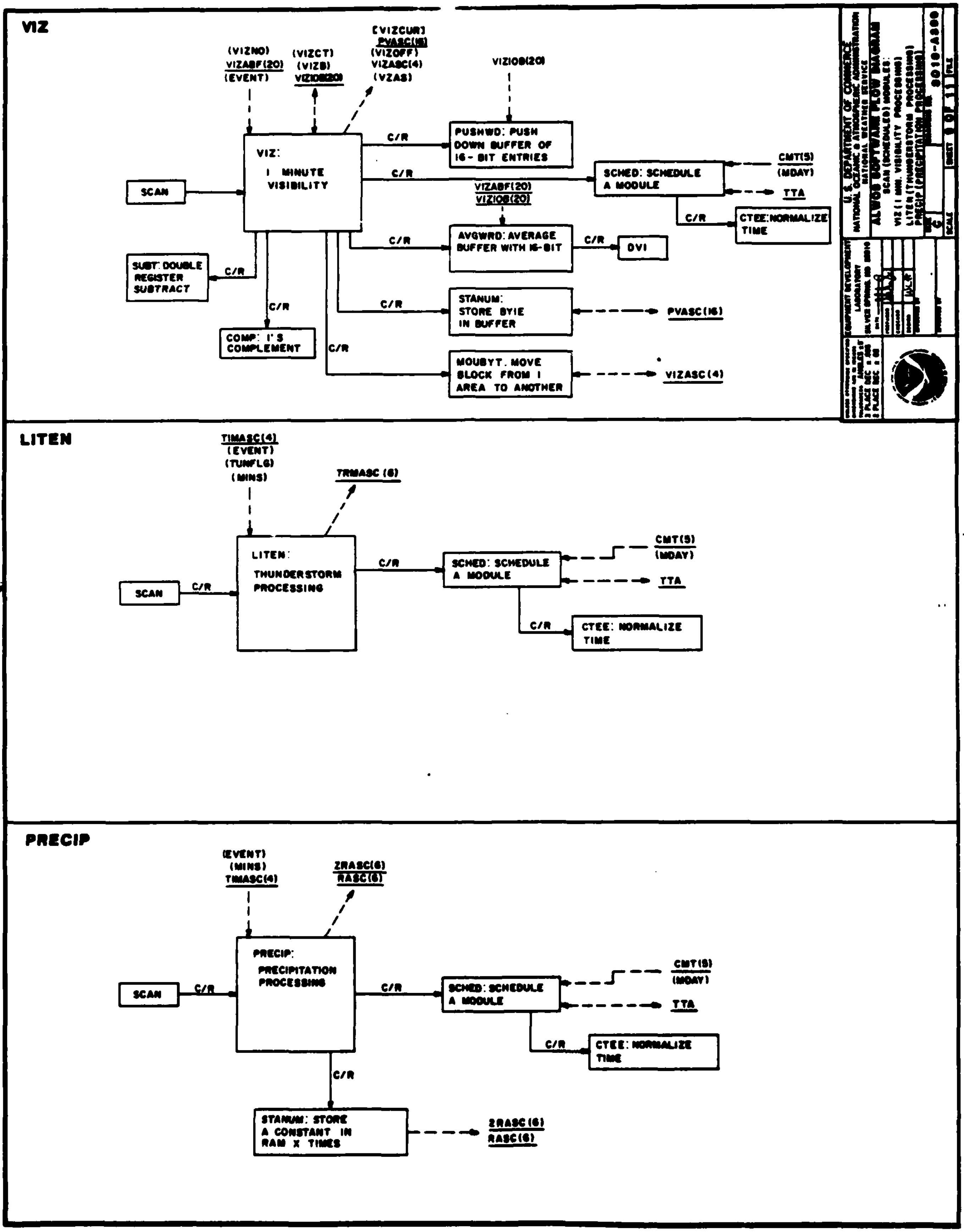

DISEXA
(UAD)
(REGFLG)
(SIZFLG)
ADTBL(32)
VIDEO RAM
SCAN
C/R
DISEXA: DISPLAY RAW DATA FOR MAINTENANCE
ADDATA: READ DATA FROM INTERNATIONAL A/D
STANUM: STORE CONSTANT
SCHED: SCHEDULE A MODULE
CMT(5)
(MDAY)
TTA
CRT: DISPLAY TO VIDEO-RAM
VIDRAM
BINASD: BINARY TO ASCII
DVI: DIVIDE
TMP
(TMPFLG)
(TIAVG)
TMPTBL(6)
TMPCUR
TIASC(5)
ADTBL(32)
MULT: MULTIPLY
SCL: CONVERT A/D COUNTS TO TEMPERATURE
DIV: DIVIDE
SUBT: SUBTRACT
TMP: 10 SECOND TEMPERATURE ACQUISITION
SCHED: SCHEDULE A MODULE
BINASD: BINARY TO ASCII
DVI: DIVIDE
TIASC(5)
TMPTBL(6)
DIV: DIVIDE
AVG: FORM AVERAGE
MOUT: OUTPUT "M" TO ASCII BUFFER
PUSHDN: PUSH DOWN BUFFER
DPT
(DPTFLG)
(DPIAVG)
DPTTBL(6)
(DPTCUR)
DPIASC(5)
DPT: 10 SECOND DEW POINT ACQUISITION
SCL: CONVERT A/D COUNT TO DEW POINT
MULT
DIV
SUBT
SCHED: SCHEDULE A MODULE
BINASD: BINARY TO ASCII
DPITBL(6)
DPIASC(5)
AVG. FORM AVERAGE
PUSHDN: PUSH DOWN BUFFER
U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC & ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE
ALWOS SOFTWARE FLOW DIAGRAM
SCAN (SCHEDULED MODULES):
DISEXA (DISP. RAW DATA)
TMP (10 SEC. TEMP SAMPLE)
DPT (10 SEC. DEW POINT SAMPLE)
EQUIPMENT DEVELOPMENT LABORATORY
SILVER SPRING, MD. 20910
8010-A800
SCALE

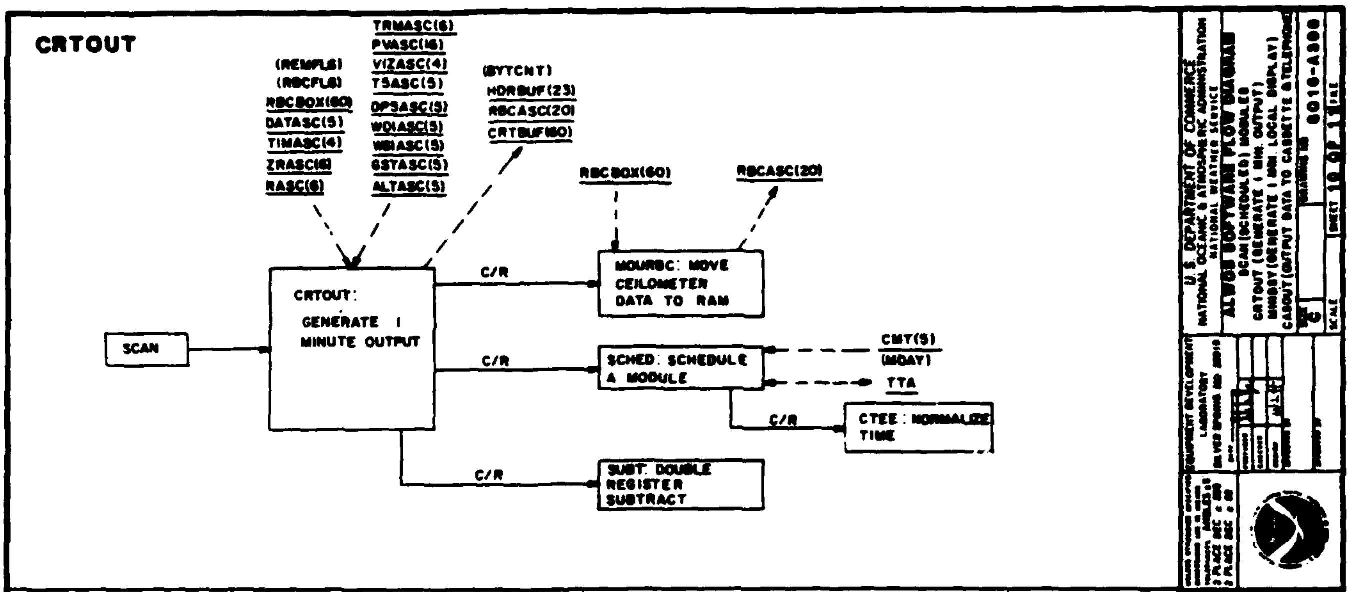

VISACQ
ADTBL(32)
VISABF(12)
UIZNG
SCAN
C/R
VISACQ: 10 SECOND VISIBILITY ACQUISITION
SCHED: SCHEDULE A MODULE
CMT(5)
(MDAY)
TTA
VISABF(12)
PUSHWD - PUSH BUFFER WITH 16-BIT ENTRIES DOWN
SUBT: DOUBLE REG SUBTRACT
CTEE: NORMALIZE TIME
TEMP
(TMPMAX)
(TMPMIN)
T5TBL(5)
(TMPC)
(TMPCNT)
(T1AVG)
T5ASC(5)
(T5AVG)
T5TBL(5)
TEMP: 1 MINUTE TEMPERATURE PROCESSING
PUSHDN: PUSH 8-BIT ENTRY BUFFER DOWN
SCHED: SCHEDULE A MODULE
CTEE: NORMALIZE TIME
T5ASC(5)
BINASD: BINARY TO ASCII
DIV
T5TBL(5)
(T5AVG)
AVG: FORM AVERAGE
SUBT: DBL REGISTER SUBTRACT
T5ASC(5)
MOUT: PUT "M" IN ASCII BUFFER
DEWPT
DPSTBL(5)
(DPCT)
(DPTCNT)
(T5AVG)
(DP1AVG)
DPSASC(5)
(DPSAVG)
DPSTBL(5)
PUSHDN: PUSH DOWN 8-BIT BUFFER
DEWPT: 1 MINUTE DEW-POINT PROCESSING
SCHED: SCHEDULE A MODULE
CTEE: NORMALIZE TIME
DPSASC(5)
SUBT-DOUBLE REGISTER SUBTRACT
BINASD: BINARY TO ASCII
DIV
DPSTBL(5)
DPSAVG
DPSASC(5)
AVG: FORM AVERAGE
MOUT: PUT "M" IN ASCII BUFFER
U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC & ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE
ALWOS SOFTWARE FLOW DIAGRAM
EQUIPMENT DEVELOPMENT LABORATORY
SILVER SPRING MD 20910
SCALE
SHEET
6010-A900

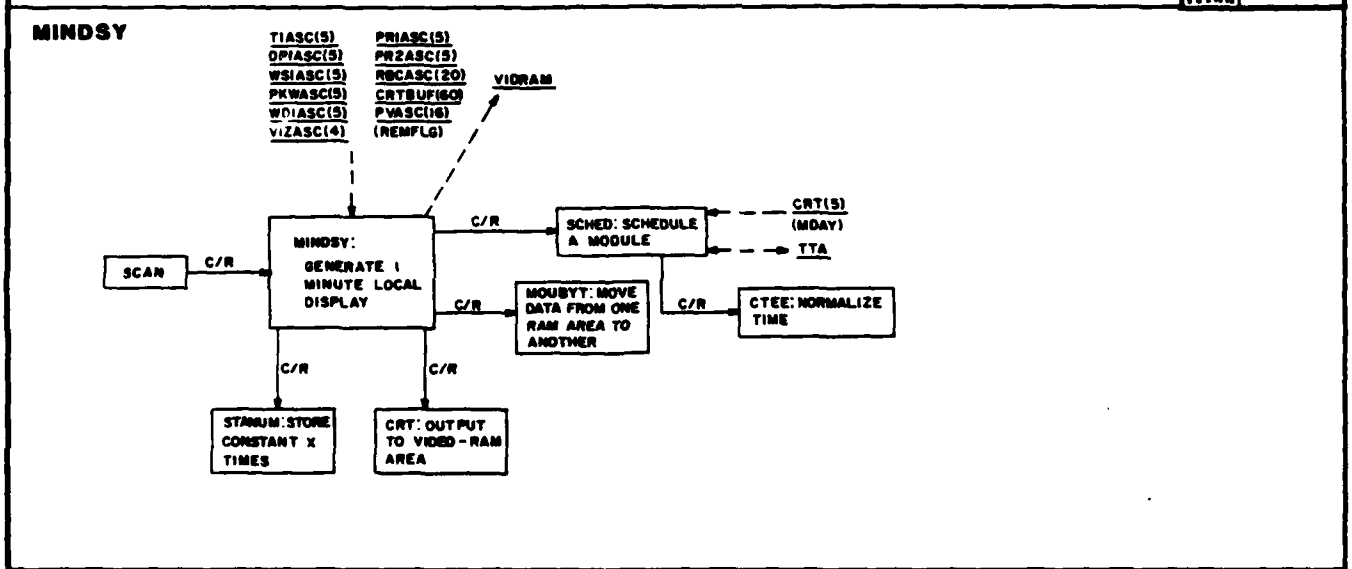

WINDSPD
SCAN
C/R
WNDSPD: I MINUTE WIND SPEED PROCESSING
WSIOTB(IO)
(WSIAVG)
(WSIOAV)
WSIOAS(5)
WSIOTB(IO)
PUSHDN: PUSH DOWN BUFFER
SCHED: SCHEDULE A MODULE
CMT(5)
(MDAY)
(TTA)
CTEE: NORMALIZE TIME
WSIOAS(5)
TSIOTB(IO)
BINASD: BINARY TO ASCII
DVI
MOUT: PUT "M" IN ASCII BUFFER
AVG: FORM AVERAGE
U.S. DEPARTMENT OF COMMERCE
GUST
(WSIAVG)
WSITBL(60)
GSTTBL(IO)
GSTCUR
GSTASC(5)
PKASC(5)
GSTTBL(IO)
SCAN
GUST: CALCULATE IO MINUTE GUST AND I MINUTE PEAK WIND
PUSHDN: PUSH DOWN BUFFER
SCHED: SCHEDULE A MODULE
CMT(5)
(MDAY)
TTA
GSTASC(5)
PKASC(5)
CTEE: NORMALIZE TIME
BINASD: BINARY TO ASCII
DIV
PRSPC1
PRSIOF(I2)
PRS2OF(I2)
(PRSERR)
(PRIERF)
(PR2ERF)
[PRICUR]
[PR2CUR]
PRIASC(5)
PR2ASC(5)
ALTASC(5)
PRSIOF(I2)
PRS2OF(I2)
SCAN
PRSPCI: I MINUTE PRESSURE PROCESSING
AVGWRD: AVERAGE BUFFER OF I6-BIT ENTRIES
DIV
MULT
DVI
SUBT
PR2ASC(5)
PRIASC(5)
ALTASC(5)
CDRDH: DOUBLE REGISTER COMPARE
BINASD: BINARY TO ASCII
MOUT: PUT "M" IN ASCII BUFFER
SCHED: SCHEDULE A MODULE
CMT(5)
(MDAY)
TTA
CTEE: NORMALIZE TIME
SHFTRD: DOUBLE REGISTER RIGHT SHIFT

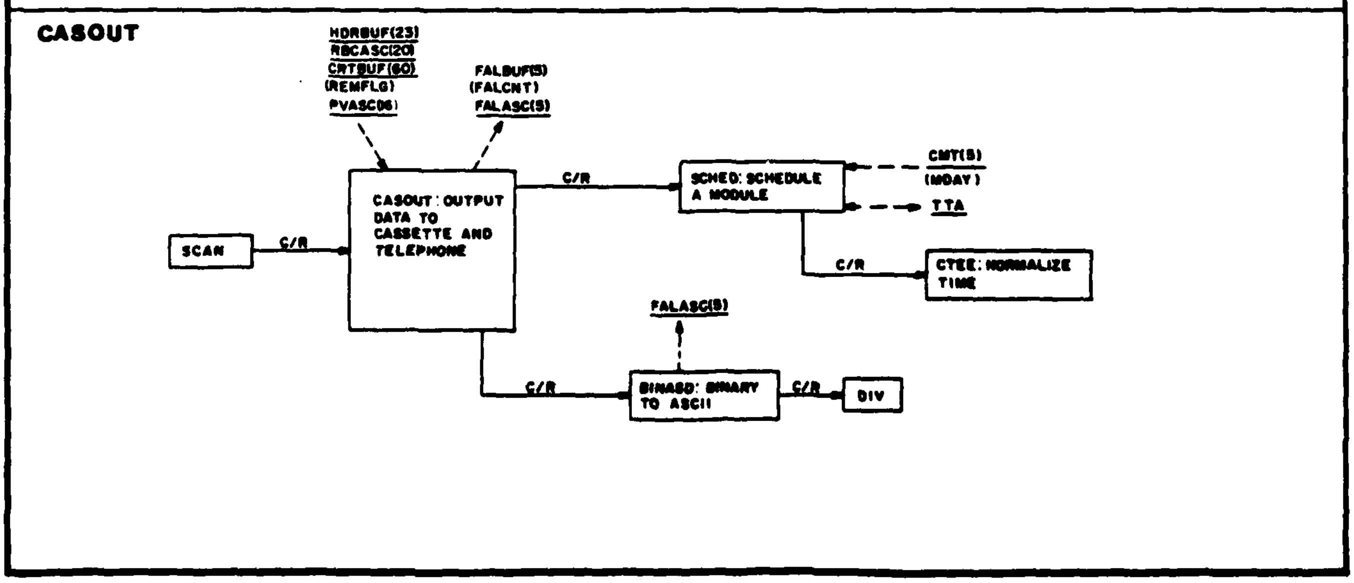


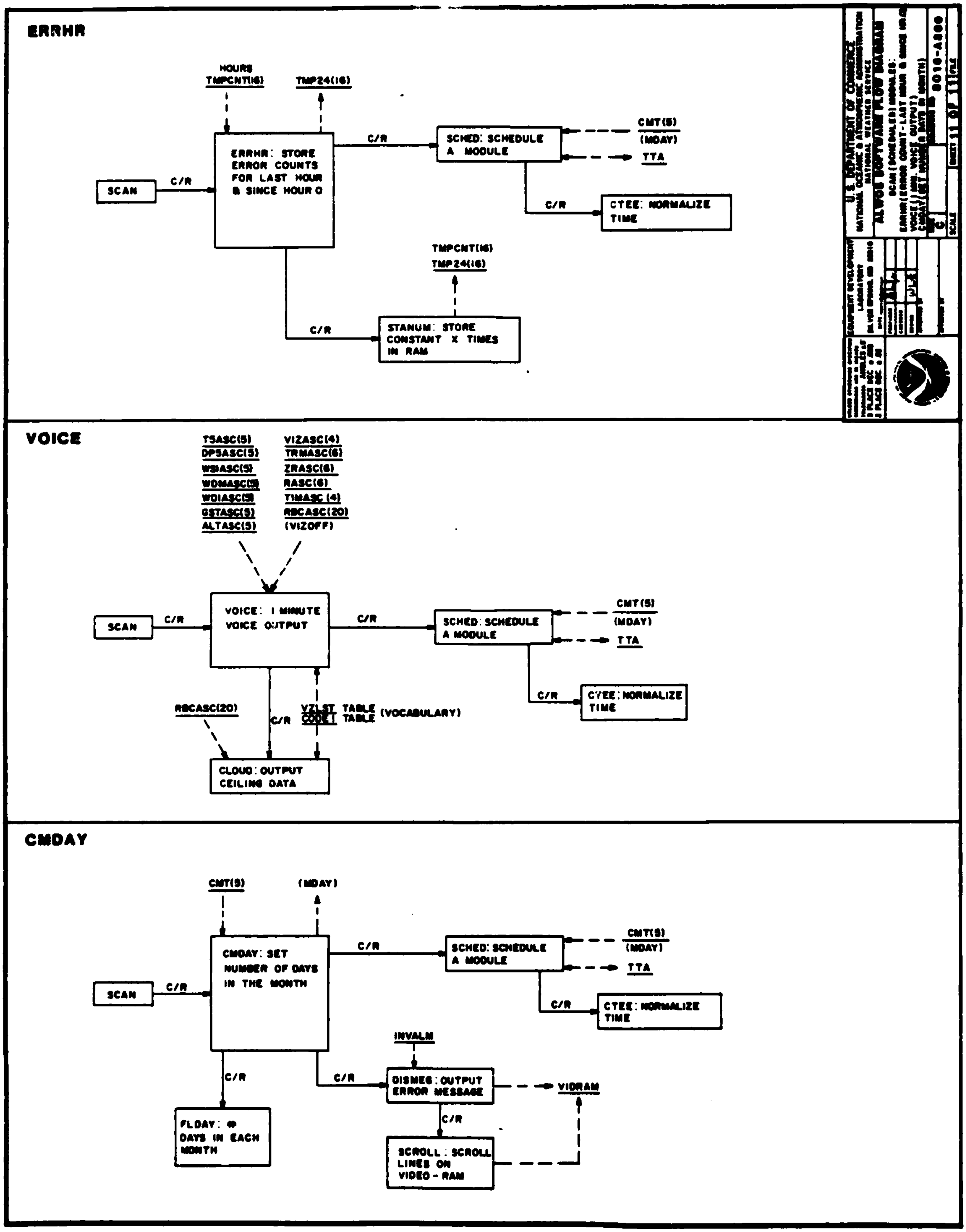
CALINT
(CALERR)
(CALFLG)
CALINT: 10 SEC. PRESSURE CALIBRATION VOLTAGE CHECK
SCAN
C/R
ADDATA: READ CALIBRATION VOLTAGE
SCHED: SCHEDULE A MODULE
CMT(5)
(MDAY)
TTA
CTEE: NORMALIZE TIME
MSG(20)
DISMSG: OUTPUT DISPLAY MESSAGE
VIDRAM
SUBT: 16-BIT REGISTERS SUBTRACT
PRSAQ1
[PR1ERF]
[PR1ERC]
[PRS1DA]
PRS1OF(12)
PRSAQ1: 10 SEC. ACQUISITION OF PRESSURE # VALUE
ADDATA: READ PRESSURE # 1, AND OFFSET VOLTAGE
SCHED: SCHEDULE A MODULE
CTEE: NORMALIZE TIME
PRS1OF(12)
MOVBYT: MOVE DATA FROM 1 BLOCK TO ANOTHER
SUBT: 16-BIT REGISTERS SUBTRACT
PRSAQ2
(PR2ERF)
(PR2ERC)
[PRS2DA]
PRS2OF(12)
PRSAQ2: 10 SEC. ACQUISITION OF PRESSURE # 2 VALVE
ADDATA: READ PRESSURE # 2 AND OFFSET VOLTAGE
SCHED: SCHEDULE A MODULE
CTEE: NORMALIZE TIME
MOVBYT: MOVE DATA FROM 1 BLOCK TO ANOTHER
SUBT: 16 BIT REGISTERS SUBTRACT
U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC & ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE
ALWOS SOFTWARE FLOW DIAGRAM
SCAN (SCHEDULED) MODULES:
CALINT (INTERNAL A/D CALIBRATION VOL CK)
PRSAQ1 (10 SEC RAW PRESSURE - SENSOR # 1)
PRSAQ2 (10 SEC. RAW PRESSURE - SENSOR # 2)
EQUIPMENT DEVELOPMENT LABORATORY
SILVER SPRING MD 20910
8010-A300
SHEET 8 OF 11
SCALE
FILE


VIZ
(VIZNO)
VIZABF(20)
(EVENT)
(VIZCT)
(VIZB)
VIZIOB(20)
(VIZCUR)
PVASC(16)
(VIZOFF)
VIZASC(4)
(VZAS)
VIZIOB(20)
VIZ:
1 MINUTE
VISIBILITY
SCAN
C/R
PUSHWD: PUSH
DOWN BUFFER OF
16-BIT ENTRIES
SCHED: SCHEDULE
A MODULE
CMT(5)
(MDAY)
TTA
CTEE: NORMALIZE
TIME
VIZABF(20)
VIZIOB(20)
AVGWRD: AVERAGE
BUFFER WITH 16-BIT
DVI
SUBT: DOUBLE
REGISTER
SUBTRACT
STANUM:
STORE BYTE
IN BUFFER
PVASC(16)
COMP: 1'S
COMPLEMENT
MOUBYT: MOVE
BLOCK FROM 1
AREA TO ANOTHER
VIZASC(4)
U. S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC & ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE
ALWOS SOFTWARE FLOW DIAGRAM
SCAN (SCHEDULED) MODULES:
VIZ (1 MIN. VISIBILITY PROCESSING)
LITEN (THUNDERSTORM PROCESSING)
PRECIP (PRECIPITATION PROCESSING)
8010-A990
SHEET 8 OF 11
EQUIPMENT DEVELOPMENT LABORATORY
SILVER SPRING, MD 20910
LITEN
TIMASC(4)
(EVENT)
(TUNFLG)
(MINS)
TRMASC(6)
LITEN:
THUNDERSTORM
PROCESSING
SCAN
C/R
SCHED: SCHEDULE
A MODULE
CMT(5)
(MDAY)
TTA
CTEE: NORMALIZE
TIME
PRECIP
(EVENT)
(MINS)
TIMASC(4)
ZRASC(6)
RASC(6)
PRECIP:
PRECIPITATION
PROCESSING
SCAN
C/R
SCHED: SCHEDULE
A MODULE
CMT(5)
(MDAY)
TTA
CTEE: NORMALIZE
TIME
STANUM: STORE
A CONSTANT IN
RAM X TIMES
ZRASC(6)
RASC(6)


CRTOUT
TRMASC(6)
PVASC(16)
VIZASC(4)
TSASC(5)
OPSASC(5)
WDIASC(5)
WSIASC(5)
GSTASC(5)
ALTASC(5)
(REMFLG)
(RBCFLG)
RBCBOX(60)
DATASC(5)
TIMASC(4)
ZRASC(6)
RASC(6)
(BYTCNT)
HDRBUF(23)
RBCASC(20)
CRTBUF(60)
RBCBOX(60)
RBCASC(20)
CRTOUT: GENERATE 1 MINUTE OUTPUT
SCAN
C/R
MOVRBC: MOVE CEILOMETER DATA TO RAM
SCHED: SCHEDULE A MODULE
CMT(5)
(MDAY)
TTA
CTEE: NORMALIZE TIME
SUBT: DOUBLE REGISTER SUBTRACT
U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC & ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE
ALWOS SOFTWARE FLOW DIAGRAM
SCAN (SCHEDULED) MODULES
CRTOUT (GENERATE 1 MIN. OUTPUT)
MINDSY (GENERATE 1 MIN. LOCAL DISPLAY)
CASOUT (OUTPUT DATA TO CASSETTE & TELEPHONE)
8010-A300
SHEET 10 OF 11


MINDSY
TIASC(5)
OPIASC(5)
WSIASC(5)
PKWASC(5)
WDIASC(5)
VIZASC(4)
PRIASC(5)
PR2ASC(5)
RBCASC(20)
CRTBUF(60)
PVASC(16)
(REMFLG)
VIDRAM
MINDSY: GENERATE 1 MINUTE LOCAL DISPLAY
SCAN
C/R
SCHED: SCHEDULE A MODULE
CRT(5)
(MDAY)
TTA
MOUBYT: MOVE DATA FROM ONE RAM AREA TO ANOTHER
CTEE: NORMALIZE TIME
STANUM: STORE CONSTANT X TIMES
CRT: OUTPUT TO VIDEO-RAM AREA


CASOUT
HDRBUF(23)
RBCASC(20)
CRTBUF(60)
(REMFLG)
PVASC(16)
FALBUF(5)
(FALCNT)
FALASC(5)
CASOUT: OUTPUT DATA TO CASSETTE AND TELEPHONE
SCAN
C/R
SCHED: SCHEDULE A MODULE
CMT(5)
(MDAY)
TTA
CTEE: NORMALIZE TIME
FALASC(5)
BINASD: BINARY TO ASCII
DIV


ERRHR
HOURS
TMPCNT(16)
TMP24(16)
ERRHR: STORE ERROR COUNTS FOR LAST HOUR & SINCE HOUR 0
SCAN
C/R
SCHED: SCHEDULE A MODULE
CMT(5)
(MDAY)
TTA
CTEE: NORMALIZE TIME
TMPCNT(16)
TMP24(16)
STANUM: STORE CONSTANT X TIMES IN RAM
VOICE
T5ASC(5)
DP5ASC(5)
WSIASC(5)
WDMASC(5)
WDIASC(5)
GSTASC(5)
ALTASC(5)
VIZASC(4)
TRMASC(6)
ZRASC(6)
RASC(6)
TIMASC (4)
RBCASC(20)
(VIZOFF)
VOICE: 1 MINUTE VOICE OUTPUT
SCAN
C/R
SCHED: SCHEDULE A MODULE
CMT(5)
(MDAY)
TTA
CTEE: NORMALIZE TIME
RBCASC(20)
VZLST TABLE
CODE1 TABLE (VOCABULARY)
CLOUD: OUTPUT CEILING DATA
CMDAY
CMT(5)
(MDAY)
CMDAY: SET NUMBER OF DAYS IN THE MONTH
SCAN
C/R
SCHED: SCHEDULE A MODULE
CMT(5)
(MDAY)
TTA
CTEE: NORMALIZE TIME
INVALM
DISMSG: OUTPUT ERROR MESSAGE
VIDRAM
FLDAY: # DAYS IN EACH MONTH
SCROLL: SCROLL LINES ON VIDEO-RAM
U.S. DEPARTMENT OF COMMERCE
NATIONAL OCEANIC & ATMOSPHERIC ADMINISTRATION
NATIONAL WEATHER SERVICE
ALWOS SOFTWARE FLOW DIAGRAM
SCAN (SCHEDULED) MODULES:
ERRHR (ERROR COUNT-LAST HOUR & SINCE HR 0)
VOICE (1 MIN. VOICE OUTPUT)
CMDAY (SET NUMBER DAYS IN MONTH)
8010-A300
C
SHEET 11 OF 11
SCALE
EQUIPMENT DEVELOPMENT LABORATORY
SILVER SPRING, MD 20910